R E P O R T R E S U M E S

ED 002 986 24

A PROGRAM FOR THE PROCESSING OF ORDINAL DATA AND COMPUTATION OF SIGNIFICANCE FOR SELECTED CENTRAL TENDENCY DIFFERENCES, VOLUME C--STUDIES IN THE ROLE OF THE PUBLIC SCHOOL TEACHER.

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REPORT NUMBER CRP-371-VOL-C PUB DATE FEB 61
EDRS PRICE MF-$0.18 HC-$2.92 73P.

DESCRIPTORS- *COMPUTER PROGRAMS, COMPUTERS, *STATISTICAL ANALYSIS, STATISTICAL DATA, STATISTICAL STUDIES, STATISTICAL SURVEYS, *TEACHER ROLE, TEACHERS, *METHODS RESEARCH, SOCIAL SCIENCES, RESEARCH METHODOLOGY, EDUCATIONAL RESEARCH, RESEARCH TOOLS, QUESTIONNAIRES, *TESTS OF SIGNIFICANCE, COLUMBIA, MISSOURI, MANN-WHITNEY MEASURES

COMPUTER PROGRAMS AND OPERATING INSTRUCTIONS WERE REPORTED FOR USE IN PROCESSING DATA ON TEACHER ROLES. INCLUDED IN THE OVERALL DATA-PROCESSING METHOD WERE--(1) A PROGRAM FOR TABULATING CONTINGENCY TABLES FROM DATA ON PUNCHED CARDS, (2) A PROGRAM FOR SELECTING AND COMBINING ROWS AND CALCULATING MANN-WHITNEY MEASURES OF SIGNIFICANT DIFFERENCES BETWEEN THE TWO ROW MEANS, AND (3) TABLES FOR CALCULATING SIGNIFICANCE MEASURES FOR SMALL FREQUENCIES. DIAGRAMS ARE PROVIDED IN THE REPORT WITH INSTRUCTIONS FOR COMPUTER OPERATION. OPTIONS, METHODS, AND LIMITATIONS OF THE COMPUTER PROGRAMS ARE ALSO DISCUSSED. OTHER DOCUMENTS RELATED TO THIS PROJECT ARE ED 002 851 AND ED 002 855. (WN)

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A PROGRAM FOR THE PROCESSING OF ORDINAL DATA AND COMPUTATION OF SIGNIFICANCE FOR SELECTED CENTRAL TENDENCY DIFFERENCES

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Volume C - STUDIES IN THE ROLE OF THE PUBLIC SCHOOL TEACHER

Social Psychology Laboratory
The University of Missouri
Columbia
February 1961

Conducted Under a Contract with the Cooperative Research Program
Office of Education
Department of Health, Education, and Welfare

ED002986

Initial distribution of this report has been made to the Cooperative Research Program of the Office of Education, Department of Health, Education, and Welfare; and copies of it may be obtained on loan from depository libraries of the program.

Additional copies may be purchased from The University of Missouri Press, Building T-2, The University of Missouri, Columbia, Missouri.

Acknowledgments

A program of data processing such as is outlined here owes a debt to others. Many persons within the larger research program have contributed towards its present form. Special thanks, however, are due to: William Bennet, Lynda Coult, Roger Miller, Earl F. Rankin, Jr., Howard A. Rosencranz, Donald Smith, J. Paschal Twyman, and F. Neil Willis who have contributed materially to the present volume. Ruth Addison was typist assisted by Carol Freeman.

F O R E W O R D

In July 1958, a program of research on the role of the public school teacher was inaugurated at The University of Kansas City. This program has had three broad objectives:

1. To pursue role theory and aid in its development as a sophisticated system of analysis in social psychology.
2. To study extensively and empirically the role of the public school teacher.
3. To explore the relationships between teacher role and the problems of teacher recruitment.

These objectives have required a variety of activities. To date, staff members have engaged in: (a) The development of a consistent set of terms and distinctions applicable to role theory; (b) The systematic review of the published literature on role theory and on empirical studies of educational roles; (c) The development of a methodology applicable to the study of roles; and (d) The collection of interview data from respondents in the Kansas City metropolitan area in three field studies covering aspects of the role of the public school teacher.

In part, this research program has been supported by the Cooperative Research Program of the Office of Education, Department of Health, Education, and Welfare through two research contracts, one granted to the University of Kansas City and one granted to the University of Missouri to which the project moved in September 1960.

This volume is one of several which are submitted to the Cooperative Research Program as a Final Report. It is concerned with a method of data processing which has enabled us to examine a great many types of comparisons among ordinally scaled data. Included within the method are: (1) A program for the tabulation of large contingency tables from primary data which have been punched onto IBM cards. (2) A computer program which prepares 2 x n ---

contingency tables from larger ones by selecting and combining rows, and then calculates the Mann-Whitney z_U which is a measure of the significance of difference between the two row means. (3) Tables of significance for z_U when tabular frequencies are small. (When tabular frequencies are large, z_U approximates a normal deviate.) The programs are described, appropriate diagrams are provided, and instructions for machine operation are detailed.

Other Final Report volumes are also available from this research program. These are organized into two series. The numerical series deals with findings from our empirical investigations of teacher role in Kansas City. The alphabetic series is concerned with role theory, methods, and bibliographic reviews. A general outline of reports either already available or in preparation is provided in Figure i.i on the following page.

The materials included in this volume were originally developed for use by staff members in processing large numbers of scaled responses dealing with teacher role in Kansas City. We have, however, received numerous requests for the methods and have assembled them in this form in the hope that they may aid others who have similar problems.

Bruce J. Biddle
Ann Simpson
January 1961

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Series I - THEORETICAL, METHODOLOGICAL AND BIBLIOGRAPHIC STUDIES

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4 - Role of the Teacher and Occupational Choice

5 - Own and Attributed Cognitions for the Teacher*

6 - Type of Community and Role of the Teacher

Figure i.i

*Studies marked with an asterisk are presently available. Unmarked studies are in preparation. Additional empirical reports (not listed) will also be prepared during 1961.

Table of Contents

Page

Foreword i

Table of Contents iv

List of Figures and Tables vi

Chapter I - A Description of the Program and Its Utility

Purpose 1

Tabulator Program 3

Computer Program 4

Tables 6

Other Related Materials 6

Chapter II - A General Program for Contingency Table Preparation

Introduction

Purposes 8

Brief Description of Method. 8

Options 8

Method

Primary Data Cards 9

Table Forms 10

The Tabulator 12

Card Sorting 12

Control Panel 12

Wiring Instructions 13

Secondary Cards 21

Summary Punch 23

Operating Instructions 25

Limitations 27

Chapter III - A Computer Program for the Mann-Whitney z_U with Tied Ranks

Purposes 34

General Method and Range 34

Mann-Whitney U Test 34

Program Options 35

General Program Method 35

Card Layout 36

Selection Tape Preparation 41

Data Preparation for Paper Tape Input 43

Program Limitations 48

Chapter IV - Tables of Significance for the Mann-Whitney z_U with Small N's

The Problem 49

The Solution 50

Limitations 51

Tabular Use 53

Tables 54

List of Figures and Tables

Number	Title	Page
1.1	General Outline - Studies in the Role of the Public School Teacher	iii
2.1	Tabular Form A	11
2.2	Tabular Form B	11
2.3	Control Panel Wiring - Reading Hubs and Counter Control	14
2.4	Control Panel Wiring - Counters and Pilot Selectors	15
2.5	Control Panel Wiring - Control Functions	16
2.6	Picture - Closed and Wired Panel Assembly	17
2.7	Picture - Panel Assembly with Cover Removed	17
2.8	Piggy-back Control Panel Diagram	18
2.9	Wired Piggy-back Control Panel	22
2.10	Wired 514 Control Panel	24
2.11	Location of Tabular Information	26
2.12	Tabular Functions	30
3.1	Input Table	37
3.2	Output Table	37
3.3	Input Format as Read Into Computer	38
3.4	Sample Input Table of 10 Cards	38
3.5	Output Format	39
3.6	Sample Output From Sample Input Figure 3.4	40
3.7	Selection Tape Summary	44
3.8	Sample Selection Tape	45
3.9	Operating Instructions	46
3.10	Program Sections and Storage Allocations	47
4.1	Tables of Critical Values for z_U with Small N's	54ff

CHAPTER I

A DESCRIPTION OF THE PROGRAM AND ITS UTILITY

Purpose

Two trends may be noted in the methods of social science research during the past decade. On the one hand, there has been a refinement of statistical techniques so that relatively minute amounts of data which could not be analyzed at an earlier date may now be examined for statistical significance. On the other, there has been a growth of machine, and particularly computer, techniques so that large amounts of data may be processed and results extracted employing a minimum number of statistical clerks. In both of these processes, older statistical tools and techniques are giving way to newer methods which are either more powerful indicators of significance or are more amenable to machine computation, or both.

Like many other investigators, the authors have recently faced the tasks of analyzing large amounts of data and extracting a maximum of findings within a minimum time period. Our data consisted of ordinally scaled responses from interviews and questionnaires. In some cases, respondents chose between precoded responses to questions and thus gave not more than one response per respondent. Other sections of data consisted of answers to open-ended questions which were later coded into various category systems and for which a given respondent might have given a number of responses - or none. Finally, respondents could be arranged into any number of groups or categories in terms of various independent variables for which we also had information.

The task, then, was to analyze the effects of a number of independent variables upon a number of dependent variables where the former were a variety of categorical systems and the latter were expressible as ordinal scales of 12

or fewer points, and where in some cases respondents may have given none, one or many responses to dependent variable questions. (This is obviously a familiar problem in social science research.)

Our solution to this problem has involved the building of a two-stage program of data analysis. In the first stage, primary data cards are first punched representing both independent and dependent variable responses and containing selective deck and respondent numbers. Cards are then verified and listed (for the sake of safety). In those cases where dependent variable responses involve more than one datum per respondent, a single card is punched for each response and independent variables, respondent number and other replicated information for the respondent is summary-punched onto all cards for that respondent. Finally, primary data cards are sorted into categories, and contingency tables are tabulated where each table represents a display of one independent variable against one dependent variable. The program for contingency table tabulation represents one major focus of the method. Upon tabulation of the required contingency tables, the researcher retires to his office to examine his data and to plan further steps in the analysis. It is possible that machine analysis will terminate at this point, either because the researcher finds nothing in his data or because he sees relationships which are best handled by hand calculation.

In the second stage of analysis, the researcher decides upon a number of comparisons he wishes to make among his data. Each comparison must be in the form of two groups of respondents for whom it is desired to compare scaled responses. For instance, the investigator may wish to compare "men" against "women," "working class" against "middle class," or other such break-downs. Each comparison will be in the form of a 2-line, n-column sub-table where lines A and B represent the frequencies of response for the two groups being compared for the n scale positions. The investigator also wishes to assess

the significance of the difference between the (rank) means of the two groups within each sub-table. At an earlier date he might have utilized the "t" distribution for this comparison, but as he cannot justify the assumption of interval scales for his data, he utilizes a non-parametric equivalent, the Mann-Whitney U.

Having decided exactly which comparisons he wishes to make by summing various groups from his original contingency data, the investigator now enters the computer with: (a) A set of explicit instructions. (b) A set of secondary data cards which he previously prepared when running off his original contingency tables. The computer then assembles the desired 2 x n sub-tables of comparison, computes the row means for both rows of the sub-table, computes z_U (the Mann-Whitney deviate), and prints out all of this information including identifying information for the tables and sub-tables being processed. The investigator then checks the computed value for z_U against tables of critical values for this statistic (provided herein) and is equipped to write up his results. From the punching of the primary data cards to the writing up of results, no hand tabulation of statistics has taken place and no additional machine manipulation of cards has been necessary.

Tabulator Program

Chapter II describes a program for an IBM 402 Tabulator which is sufficiently flexible to meet requirements of the general method given above. With this program, a set of primary data cards containing separate independent and dependent variable fields can be converted into contingency tables which are automatically titled, row and column headed, and which indicate not only individual cell frequencies but also row, column and grand totals.

A number of program options are available: (1) Up to 12 columns of data may be displayed across the horizontal dimension of the table, while up to

10,000 separate tabular lines may be printed. (Ordinarily, scaled dependent variables are displayed horizontally, while independent variable groups are displayed vertically, but this is required only for later computer input of the data.) (2) Provision is made for tabulating X and Y cards to the inside of the row and column totals and adding them into the total figures; or, alternately, tabulating X and Y cards to the outside of and not adding them into row and column totals. (X and Y punches are often used in social science data to indicate missing information, non-readable answers and the like.) (3) Simultaneously with the printing of contingency tables, secondary cards may be punched corresponding to the lines of the table (by hooking together the 402 and any of several IBM Summary Punches). These cards may later be used, without alteration, for computer input. (4) Automatic control of line spacing is provided within the table, and automatic skipping from table to table may take place when successive tables are being prepared from a large group of primary cards. (5) Provision is made for the ignoring of duplicate responses, that is, for the counting of only the first card from a given respondent and the ignoring of subsequent response cards in a given response category.

Wiring diagrams are provided both for a standard 402 control panel and for a modified control panel (which is described and pictured). Machine functions and control instructions are given, and limitations of the program are discussed.

Computer Program

Chapter III describes a computer program for the assembly of an indefinite number of 2-row sub-tables out of any given contingency table, the calculation of means for both rows and z_U in comparison of the two rows, and the printing out of the sub-table, its statistics and identification information. The

program is designed and described for a Burroughs Datatron computer, although it can be adopted to an IBM 650 or any other computer with sufficient storage capacity. With the Datatron, sub-tables and their associated statistics are prepared at the rate of approximately one every six seconds.

A number of options are available in connection with this computer program: (1) Secondary card input may be used where cards are identical to those produced for the purpose by the 402-Summary Punch hook-up as described above. Alternately, magnetic or paper tape input may be utilized. (2) Output may be printed directly in tabular form or may be punched into cards, in which latter case the cards so punched are also in "secondary" form and may be used at a later date for additional computer input. (3) Speed-up options are available which appreciably shorten the program when small n's are anticipated within the data. (4) A wide variety of lines may be chosen from the original contingency table for summing in either row of the sub-table, and those rows selected are identified within the output information. (5) Comparisons may be made for any ordinal scales of up to 12 positions, and among 99 separate input lines (groups) and their combinations. (6) The second row of the sub-table may be inverted and z_U computed on a comparison between the normal first and inverted second rows. This option is useful when theory suggests that a test should be made against the null hypothesis of a mirrored (rather than identical) rank distribution.

A thorough discussion of options, methods and limitations is given for this program. Sample tables are provided together with their analyses. Instructions for operation of the Datatron are discussed. Available from the authors (but not included here) are flow charts, tables of storage allocation and the program itself (available on paper tape).

Tables

Chapter IV presents a set of tables designed for use with this program. Whereas it has been shown that the Mann-Whitney deviate, z_U, has the form of a normal deviate for large frequencies, when frequencies in the two rows of the sub-table are less than 20, z_U has unique properties. The tables presented in Chapter IV consist of critical values of z_U for each of eight levels of statistical significance and may be used to assess computed values of z_U when frequencies are small. For larger frequencies, z_U may be assessed against any table of areas and ordinates of the normal curve, and selected critical values of the normal deviate are also provided. Finally, a discussion of the rationale and method for computing the tables is presented.

Other Related Materials

The program described here has a variety of short-comings. First of all, it is bound to a method of contingency table preparation which is inappropriate for certain kinds of subsequent statistical analyses. Secondly, the computer program has various limitations, not the least of which is that it is designed to test only the linear differences between two rank distributions. To illustrate: (a) Let us assume a non-linear relationship between two rank distributions. Group A responses, let us assume, fall at mid-points of an ordinal scale, while Group B responses fall at extremes. The Mann-Whitney statistic is explicitly designed to ignore such differences and will give an insignificant result, as the rank means are obviously similar. To the knowledge of the authors, no ideal statistic is presently available to test this type of effect for rank data, although we would presume it bore a "family relationship" to and was independent of the Mann-Whitney U. (b) Even assuming linearly related data, there are effects (such as testing for the difference between the total frequencies involved in each row) in the sub-table which are ignored in the program.

Additional computer programs are under preparation by the author and others to be used in conjunction with the secondary data cards and contingency tables as described in Chapter I. When enough of these are available, a second volume will be prepared dealing with additional programs related to the ones described herein.

Finally, it is assumed by the authors that this program is but a stop-gap procedure designed for the perilous decade when computers are large, expensive and multi-purpose. It is our hope that within a short period of time there will be specialized computers designed explicitly for data analysis which can not only produce, on demand, contingency tables from a set of primary data cards, but which can also proceed from such data directly to the calculation of statistics of relationship, calculate their significance, and print off the results in such a form as may be needed for reporting. Until that day such programs as the one described have their utility.

CHAPTER II

A GENERAL PROGRAM FOR CONTINGENCY TABLE PREPARATION

INTRODUCTION:

Purposes

(a) To form a contingency table of n lines and m columns which displays the joint variation of two variables which are punched as distinct fields in a deck of primary data cards.

(b) To reproduce automatically the contingency table on a set of secondary cards which may be used for the later computer evaluation of these data.

Brief Description of Method

Primary data cards are punched (and verified) representing two or more classes of responses from independent sources. Cards may represent either respondents or responses. In the former case, there will ordinarily be one card for each respondent, in the latter more than one card per respondent. Cards are sorted appropriately prior to tabular preparation.

Cards are then fed into an IBM 402 Tabulator which is wired as described herein. A contingency table of n lines and m columns is then prepared in which each tabular entry represents one card (or joint display of the two chosen variables). Any two variables punched upon the primary cards may be chosen for display. Vertical and horizontal headings, tabular identification, and line, column and grand totals are printed automatically.

Should it be desired, the contingency table may be reproduced automatically upon a deck of secondary cards by attaching the 402 Tabulator to a 514 (or any other) Summary Punch. A standard card lay-out is provided for secondary cards so that they may be used for immediate computer input with no additional processing. Various computer programs are available for analyses of the data being displayed.

Options

(1) Any variables represented as fields within the primary cards may be chosen for vertical or horizontal display except that: (a) The variable displayed horizontally is limited to a single-column field ($m \leq 12$). (b) The variable displayed vertically is limited to a four-column field ($n \leq 10{,}000$).

(2) Frequencies capable of being tabulated within the table are limited to 999 (for normal tabular entries and column totals), 99 (for entries in X and Y columns and their totals), and 9999 (for entries in line totals and the grand total).

(3) Two forms of the display table are available. (a) In Tabular Form A, X's and Y's (in either the vertical or horizontal variable) are considered to not represent legitimate data. They are tabulated to the right of and below the line, column and grand totals and are not added into the totals printed. (b) In Tabular Form B, X's and Y's are considered to represent legitimate data, are tabulated within the body of the table proper, and are added into line, column and grand totals.

(4) Provision is made for the automatic ignoring of subsequent responses from any respondent within a line group. Thus, for instance, if primary data cards represent responses, and response content is the vertically displayed variable, a table may be prepared which ignores all but the first response from any individual thus counting respondents for each line. This feature may also be defeated.

(5) A Heading Line is provided for all tables which not only prints column designations but which also prints nine digits of tabular identification which may either be read from cards being processed or which may be printed arbitrarily from emitted digits. Line identification is printed for all lines (including X, Y and Total) which corresponds to the identified vertical variable group being processed.

(6) Automatic skipping may be used to begin each table at a designated position upon the page. Spacing within the body of the table may be varied for 1, 2, or 3 spaces between: (a) Lines of the table. (b) Spacing between Heading Line and the table body. (c) Spacing prior to the column total line. (d) Spacing (in Tabular Form A) between the column total line and X and Y lines.

(7) Secondary data cards may be prepared automatically which represent all lines of the table being prepared. Information on the secondary data cards may include frequencies for all data lines (including X and Y), tabular identification, and line identification.

METHOD:

Primary Data Cards

It is presumed for this program that primary data cards contain the following fields: (1) A deck number which is constant for all cards of the deck. (2) A respondent number which is not more than four columns deep. (3) Two or more variables which are desired to be related and which are punched in distinct fields not more than four columns deep. These fields may be punched at any locations in the primary data cards. Other fields may be substituted for each of the above depending upon program functions.

The program is designed for analyzing the joint variation of two variables where one of them is limited to a single column field. Should it be necessary to analyze two variables jointly where the one with the smaller field is expressed in two columns, analysis may be made by sorting cards into groups by information contained in one of the two columns and then running a number of tables corresponding to each group. Modifications of this instruction may also be made for fields of greater than two columns.

Table Forms

Sample table forms are presented in Figures 2.1 and 2.2. Figure 2.1 presents an example of Tabular Form A. The first line of this table is a heading line which presents column identification numbers and nine digits of tabular identification. It will be noted that tabular identification is in four fields. H_1, H_2, and H_3 are each two-column fields, while H_4 is a three column field. In the example given, H_3 and H_4 were not entered with tabular identification data. All tabular identification fields normally print but may be suppressed if desired. Note that whereas the X column is identified with an asterisk that the Y and Total columns are not identified. It should also be noted that in Tabular Form A the X's and Y's print to the outside of the Totals (and are not added in).

Two printed data lines are given in Figure 2.1. Each is identified to the left with a Line Identification Number. Four digits are normally printed. If it is desired, any of these digits may be suppressed. The data entries in each line represent numbers of cards counted (or numbers of comparisons tabulated). Entries are totaled in the total column to the right. X and Y punches are also counted for each line but are not totaled. Frequencies of zero are not printed.

A single line of column totals is then printed which is not identified with a line identification number and which also has an asterisk printed beside the grand total. Column totals and grand totals represent a summation of their respective columns. X and Y columns are also summed, but are not added into the grand total. Once again, frequencies of zero are not printed.

Finally, separate lines are printed representing those cards punched X and Y on the vertical dimension. The X line is identified by an asterisk in the H_3 field; the Y line is otherwise unidentified. X's and Y's (from the vertical variable) are summed in the total column but not added into the grand total. Appearing in the lower right hand corner of the table is a tabulation of those cards which were punched X and Y in <u>both</u> vertical and horizontal dimensions. These cards are not summed anywhere. (It is presumed in this program that X and Y cards for the vertical variable will be punched consistently "XXXX" throughout the field. Cards with a variety of punches, for instance "XXXY," may be sorted into separate groups and will be printed on distinct lines of the table. They will be unidentified in tabular printing, however. Discrimination of the asterisk which identifies the X line of the table is made upon the low order (digit) position of the line identification (or vertical variable) field.)

Figure 2.2 presents an example of Tabular Form B. The same cards were processed in this example as were processed in Figure 2.1 and most features of the table are identical to those of Tabular Form A. It will be noted, however, that X's and Y's are included within Tabular Form B and are counted in all cases within the line, column and grand totals. Line identification is identical for Tabular Form B, while column identification is identical except that the X column is identified with a credit sign (CR) rather than an asterisk.

The distinction between Tabular Forms A and B is provided in order to accommodate the various uses of X and Y punches in data cards. Common usage is to utilize X and Y punches for missing data, questions not answered, unreadable material and the like. When so used, Tabular Form A would be appropriate, as it is generally not desired to include "non-answers" to questions in a Total N figure. When X and Y are used for data (as in those cases when a 12-category code is indicated with all 12 categories as meaningful data), Tabular Form B should be used.

Figure 2.1 - Tabular Form A

Tabular Identification Numbers H_1	Tabular Identification Numbers H_2	Line Identification Numbers	Column Identification Numbers	Totals	X's	Y's	Tabular Identification Numbers H_3	Tabular Identification Numbers H_4	
01	23		0 1 2 3 4 5 6 7 8 9		*		00	000	Heading
		0123	1 2 3	6	1	1			Data
		0124	1	1					Lines
			1 2 3 1	7*	1	1			Totals
		0000	1 1	2	1		*		X's
		0000				1			Y's

Figure 2.2 - Tabular Form B

Tabular Identification Numbers H_1	Tabular Identification Numbers H_2	Iine Identification Numbers	Column Identification Numbers	X's	Y's	Total	Tabular Identification Numbers H_3	Tabular Identification Numbers H_4	
01	23		0 1 2 3 4 5 6 7 8 9	CR			00	000	Heading
		0123	1 2 3	1	1	8			
		0124	1			1			Data
		0000	1 1	1		3	*		X's Lines
		0000			1	1			Y's
			1 2 3 1 1 1	2	2	13*			Totals

The Tabulator

The IBM 402 Tabulator is a general purpose machine for preparing tabular information on forms or sheets of paper from punched cards. Its use in this program is specific and controlled by a pre-wired control panel. The 402 Tabulator to be used must be modified over standard issue models in the following regards: All 16 pilot selectors, all 12 co-selectors, and both digit selectors are needed. Standard provisions are used for attaching the 402 Tabulator to a 514 (or other) IBM Summary Punch for the preparation of secondary cards. It is assumed that the reader is minimally familiar with the 402 Tabulator and its operation in the discussion which follows:

Card Sorting

Prior to entering primary data cards into the 402 Tabulator they must be sorted. The basic sort consists of arranging each deck of cards corresponding to a table into a sequence of groups where each group represents one line of the table to be prepared. Sorting takes place on the field of the vertical dimension, and each group must have a single line identification number corresponding to one integer of the vertical variable. Ordering of the line groups may be made at will, except that in Tabular Form A the presence of an X or Y line group will always initiate the printing of a total line summarizing data lines previously printed, while X and Y lines will never themselves be added into the total line. It is implied that X and Y line groups should always be placed at the end of each deck designed to produce a table of Form A, while decks for Tabular Form B may show line groups in any order whatsoever. (Ordering along the variable being displayed horizontally is automatic. No sorting of cards is necessary, and no changing of tabular lay-out may be made without extensive panel wiring revisions.)

A secondary card sort is used if only one card is to be counted for each respondent. The entire deck of cards is first sorted on respondent number, thus bringing together all responses of each respondent. Then the basic sort is made as usual. As a result, respondents are ordered within each line group, and all cards representing responses from a given respondent will be found together within the line group.

Control Panel

A standard 402 Tabulator Control Panel may be used for the program, but wiring tends to be quite complex. Figures 2.3, 2.4 and 2.5 deal with basic control panel wiring. In the author's experience, it is difficult to work with this program with a non-modified board and untrained personnel. Consequently, the following modifications were made, and a description of the program will be given in terms of the modified panel:

A Semi-Fixed Control Panel (IBM 292660) was purchased. This unit consists of a steel cover for the 402 Control Panel, mounting hardware, and a "piggy back" control panel consisting of 160 hubs arranged in 8 rows of twenty. In normal use, the piggy-back control panel (known as a Semi-Fixed Panel Assembly - IBM 178773) is mounted flush with the top of the steel cover, standard hook-up wires are run from the back of the piggy-back panel to hubs of the normal 402 control panel, and control of the 402 is affected from the face of the piggy-back panel. For the program described herein, additional hubs are needed for control purposes. Consequently, a second piggy-back panel was purchased,

sawed in half, glued and pegged to the original piggy-back panel, and mounted together with the original panel at the top of the steel cover. Mounting necessitated cutting a larger hole in the steel cover and the cutting and gluing of both piggy-back panels (which are made of a tough thermo-setting plastic). The resulting arrangement provides 240 hubs of control function which are available on the top of steel panel arranged in 12 rows of twenty. Figure 2.6 shows the completed assembly ready for installation in the 402. Figure 2.7 is a picture of the assembly with the steel cover removed.

Figure 2.8 is a diagram of the piggy-back panel and will be discussed extensively in the following section. It will be observed that all hubs are identified with a lower case letter and a number; thus, hub a-1 is in the upper left hand corner of the panel, while hub 1-20 is in the lower right hand corner. It will be observed that in Figures 2.3, 2.4, and 2.5 reference is made to hubs so identified. Wiring will normally go from the 402 panel hubs so indicated to the piggy-back panel hubs (at the rear). Function discussion will be entirely in terms of the piggy-back panel hubs. Translation may be made to the normal 402 control panel by reference to the hub identification given in Figures 2.3, 2.4, and 2.5.

Wiring Instructions

In the following instructions, reference is given to Figure 2.8. Figure 2.9 gives an example of a fully wired panel.

1. Second Reading (a-d, 1-20). Second Reading consists of 80 hubs which are wired to the 80 Second Reading hubs of the normal 402 panel. Impulses from these hubs are available from all 80 columns of the "next card" (the card to be processed next at the Third Reading hubs). These impulses are available to set up machine functions. They are normally wired to Line Control, Tabular Control, Duplicate Card Control, and to (·).

2. Third Reading (e-h, 1-20). Third Reading consists of 80 hubs which are identical to the 80 Third Reading hubs of the normal 402 panel. Impulses from these hubs are available from all 80 columns of the card currently being processed. These hubs are normally wired to Line Control, Tabular Control, Duplicate Control, and Heading Entry.

3. Line Control (i-j, 9-12). Line Control consists of 8 hubs which are arranged in two rows of four; controls the recognition of new line groups by detecting a card with a different line control field at the Second Reading hubs; initiates the printing of line totals, spacing, and the printing of row identification numbers. Wiring normally goes from the Second and Third Reading hubs to the corresponding rows of Line Control. The line control field (vertical variable field) may consist of any 1, 2, 3, or 4 columns in the card, but wiring from the Second and Third Reading hubs must be identical. The line control field is wired so that the digits (low order) position of the field is wired to the right hand hubs of Line Control.

Unused positions of Line Control (1, 2, or 3 depending upon the size of the line control field) may be used to transfer tabular or other identification to the Summary Punch. Wire from the Third Reading hubs (for information from the line group being processed) or from Digit Emit (for arbitrary tabular information), and split each impulse so that it goes into both rows of Line Control.

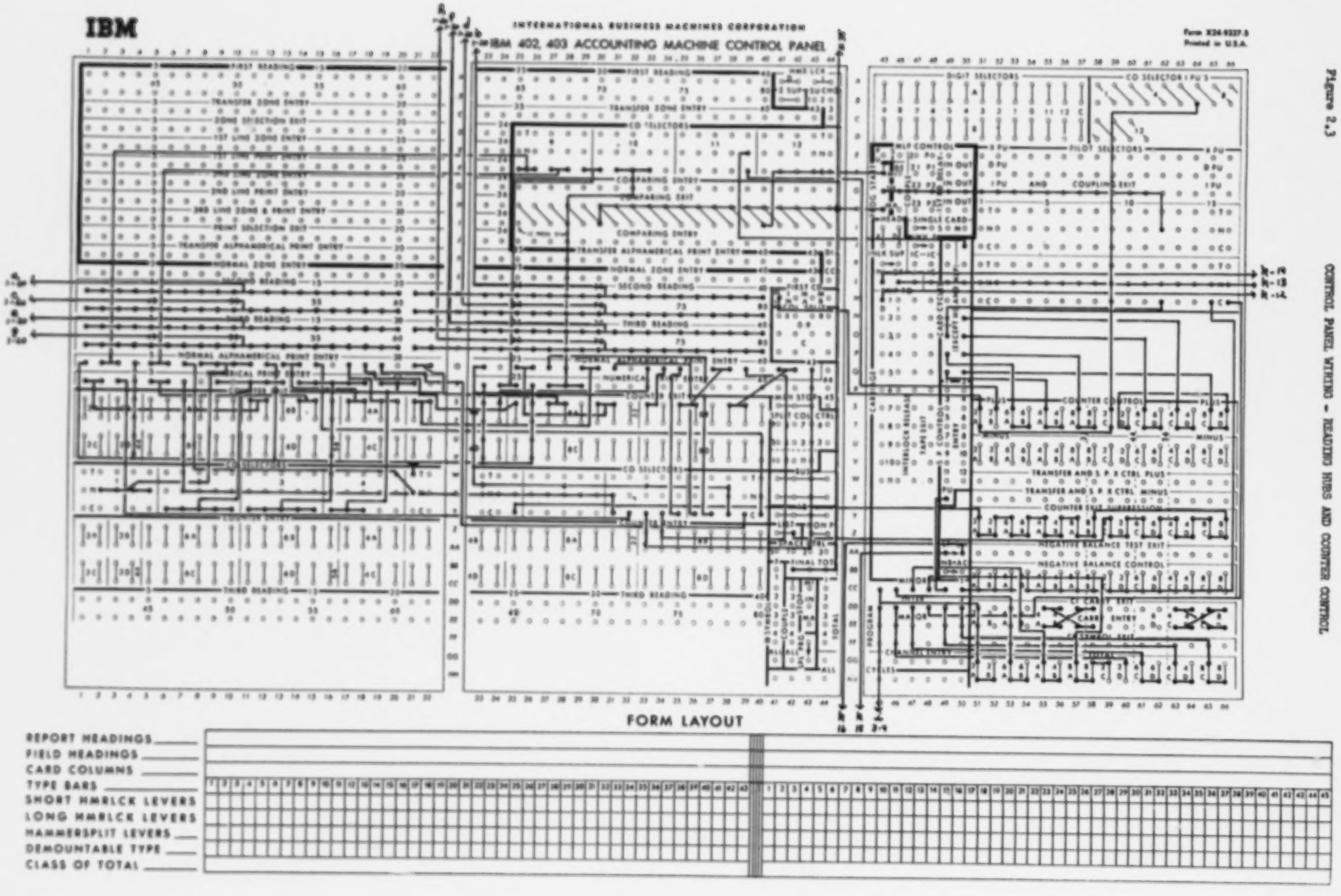


Figure 2-3 CONTROL PANEL WIRING - READING HUBS AND COUNTER CONTROL

IBM

INTERNATIONAL BUSINESS MACHINES CORPORATION

IBM 402, 403 ACCOUNTING MACHINE CONTROL PANEL

Form X24-9237-1
Printed in U.S.A.

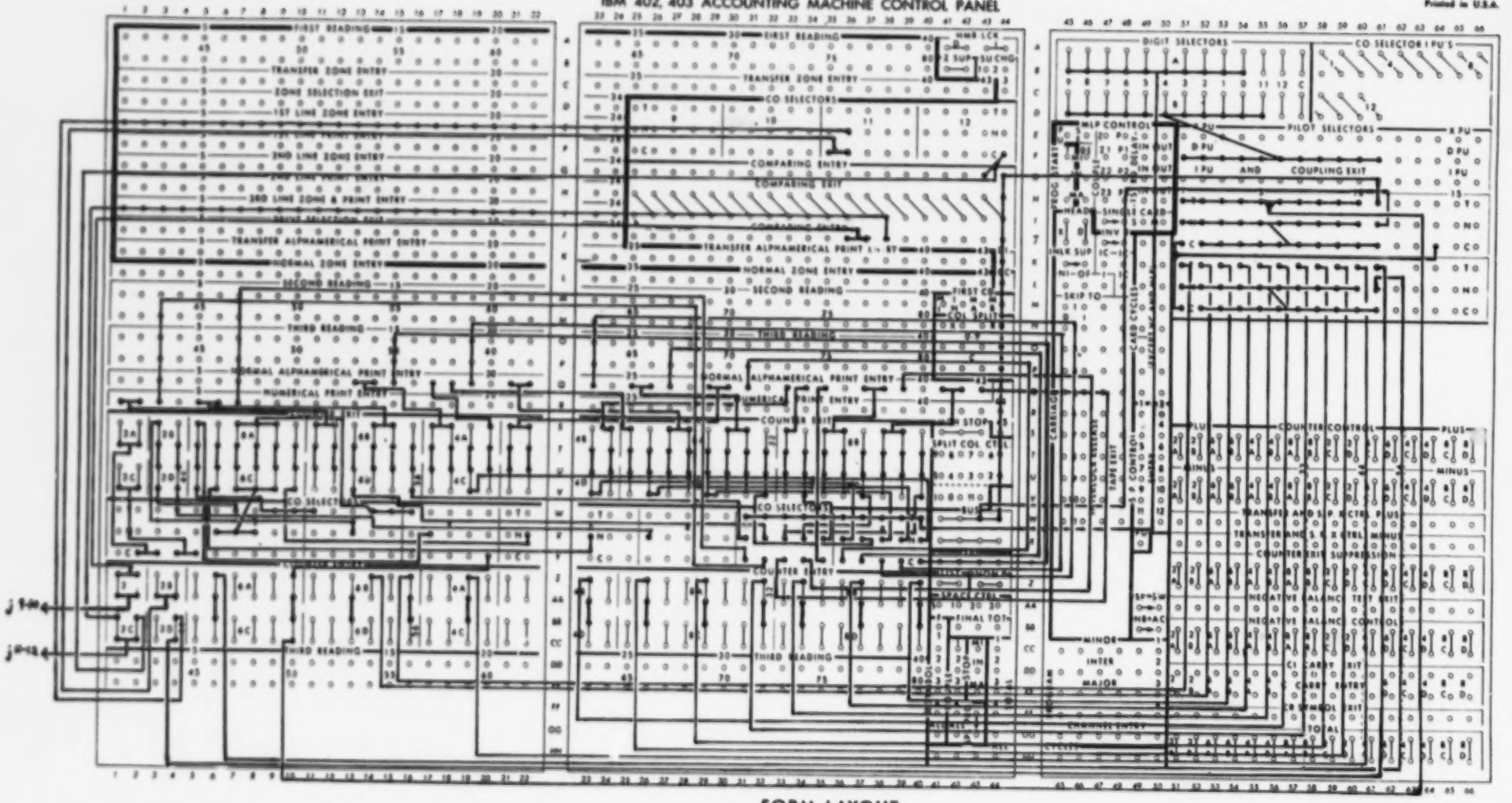


Figure 2.4

CONTROL PANEL WIRING - COUNTERS AND PILOT SELECTORS

FORM LAYOUT

REPORT HEADINGS
FIELD HEADINGS
CARD COLUMNS
TYPE BARS
SHORT HMRLCK LEVERS
LONG HMRLCK LEVERS
HAMMERSPLIT LEVERS
DEMOUNTABLE TYPE
CLASS OF TOTAL

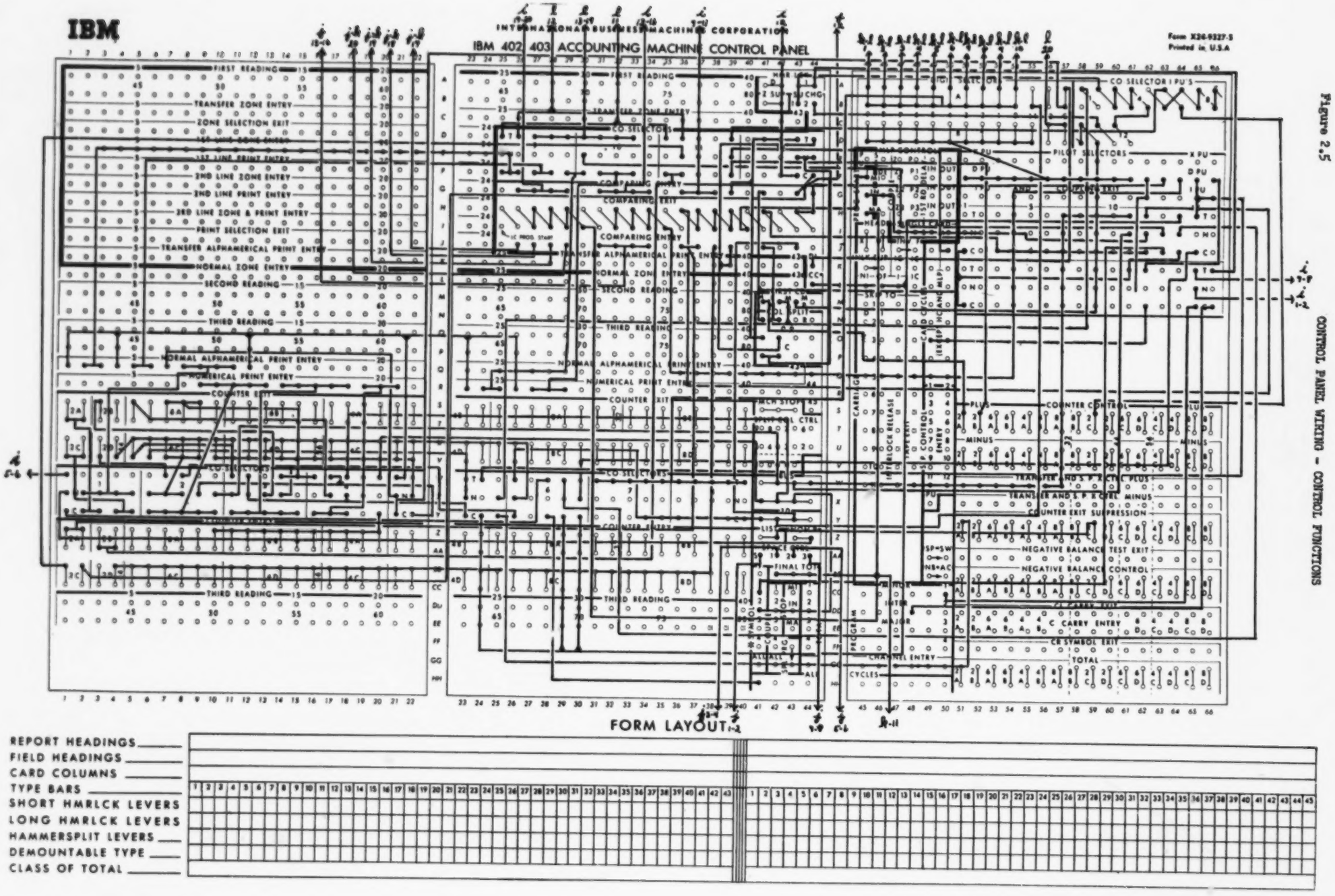


Figure 2.5 CONTROL PANEL WIRING - CONTROL FUNCTIONS

Figure 2.6 - Closed & Wired Panel Assembly

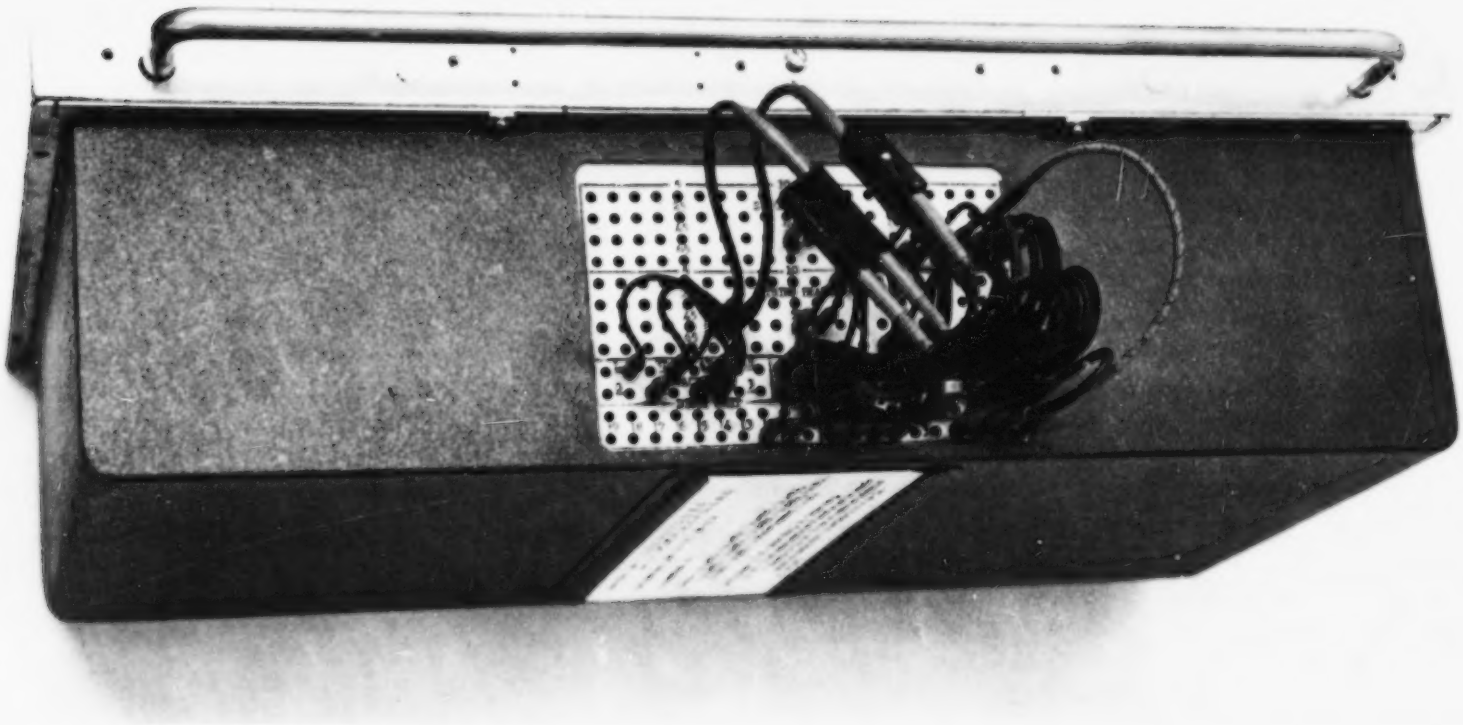


Figure 2.7 - Panel Assembly with Cover Removed

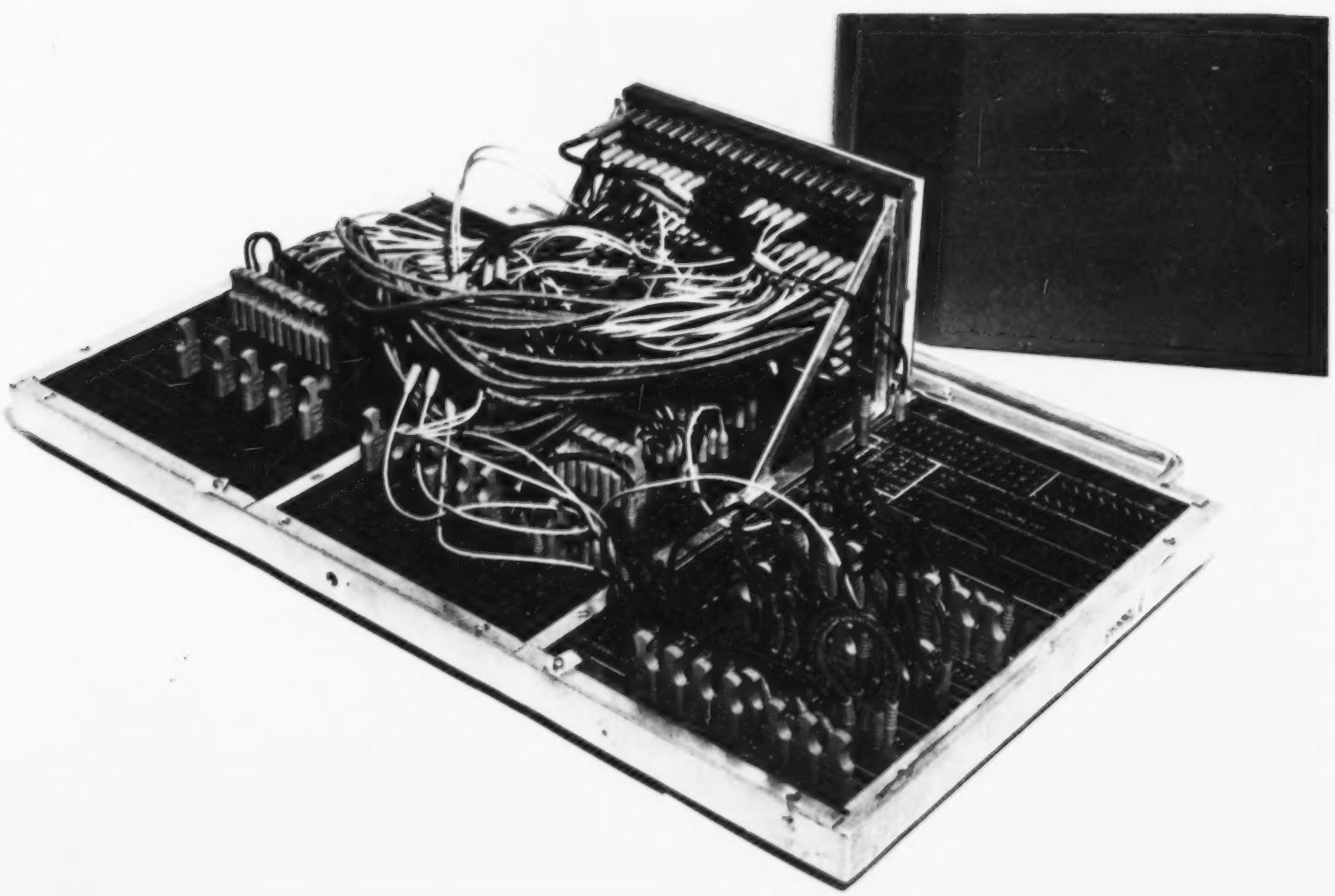
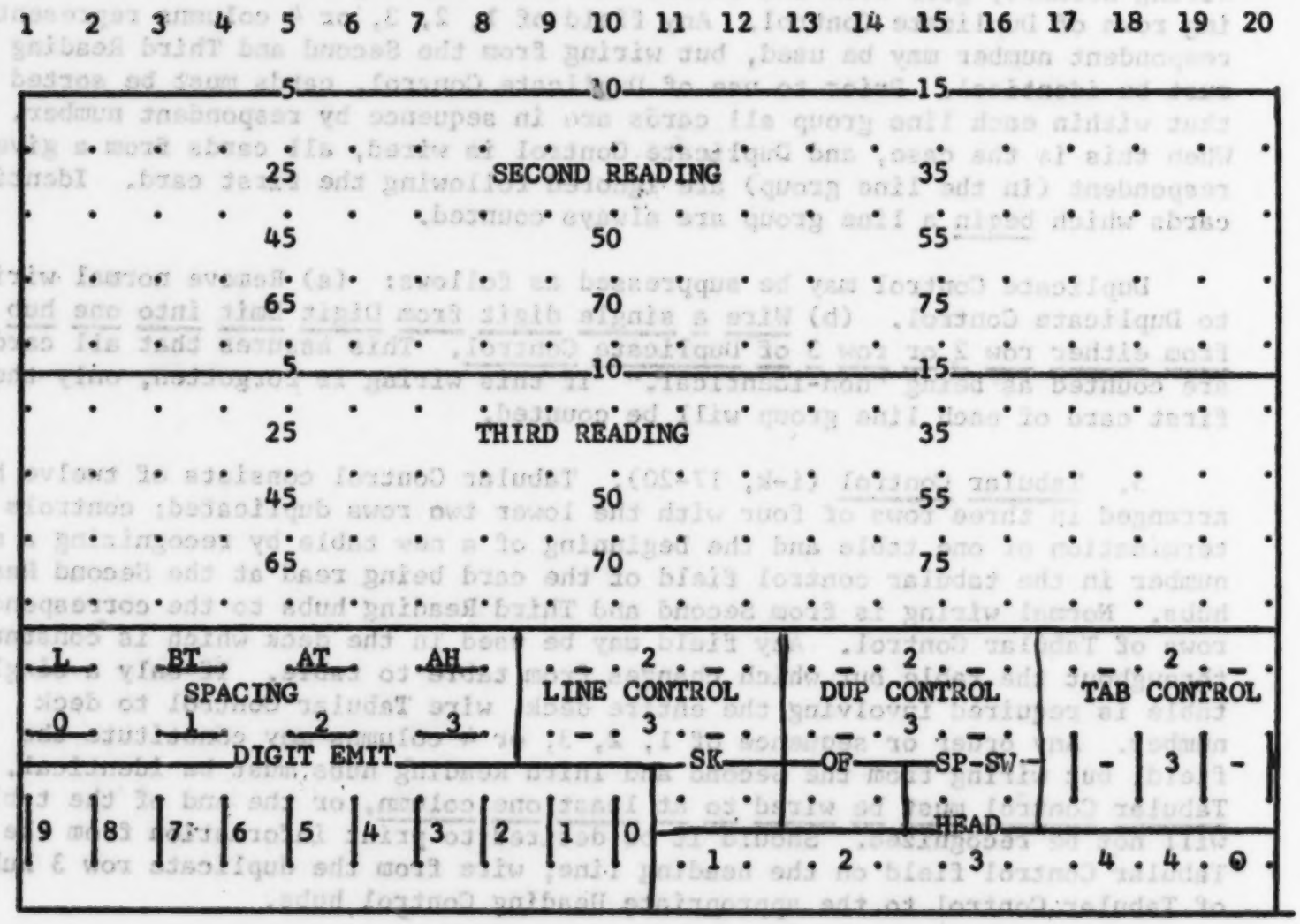


Figure 2.8—Piggy-back Control Panel



Do not split wire into the right hand hubs of Line Control. Use short hammerlocks Alphameric 8, 9, and 10 as needed to block printing of this additional information on the table being prepared. Line Control information is available at the Summary Punch in Counters 2A and 2C, with 2C having the low-order (tens and digits) positions.

4. Duplicate Control (i-j, 13-16). Duplicate Control consists of eight hubs arranged in two rows of four; controls the recognition of a duplicate card from a given respondent by comparing a respondent number field read at the Third Reading hubs with a similar field from the next card at the Second Reading hubs; suppresses counting for all duplicate cards except those in a new line group. Wiring normally goes from the Second and Third Reading hubs to the corresponding rows of Duplicate Control. Any field of 1, 2, 3, or 4 columns representing respondent number may be used, but wiring from the Second and Third Reading hubs must be identical. Prior to use of Duplicate Control, cards must be sorted so that within each line group all cards are in sequence by respondent number. When this is the case, and Duplicate Control is wired, all cards from a given respondent (in the line group) are ignored following the first card. Identical cards which begin a line group are always counted.

Duplicate Control may be suppressed as follows: (a) Remove normal wiring to Duplicate Control. (b) Wire a single digit from Digit Emit into one hub from either row 2 or row 3 of Duplicate Control. This assures that all cards are counted as being "non-identical." If this wiring is forgotten, only the first card of each line group will be counted.

5. Tabular Control (i-k, 17-20). Tabular Control consists of twelve hubs arranged in three rows of four with the lower two rows duplicated; controls the termination of one table and the beginning of a new table by recognizing a new number in the tabular control field of the card being read at the Second Reading hubs. Normal wiring is from Second and Third Reading hubs to the corresponding rows of Tabular Control. Any field may be used in the deck which is constant throughout the table but which changes from table to table. If only a single table is required involving the entire deck, wire Tabular Control to deck number. Any order or sequence of 1, 2, 3, or 4 columns may constitute the field, but wiring from the Second and Third Reading hubs must be identical. Tabular Control must be wired to at least one column, or the end of the table will not be recognized. Should it be desired to print information from the Tabular Control field on the heading line, wire from the duplicate row 3 hubs of Tabular Control to the appropriate Heading Control hubs.

6. Spacing (i-j, 1-8). Spacing consists of 16 hubs arranged in 8 pairs where each pair is a common entry to or exit from an explicit spacing function. The numbered hubs accept impulses for spacing purposes. When "0" is impulsed, all spacing is suppressed for the cycle concerned. When "1," "2," or "3" are impulsed, a corresponding spacing takes place on the cycle concerned. "L" emits an impulse prior to the printing of each data line including X and Y lines (but excluding the first tabular line after the heading line). Impulses from "L" may be used to space none, one, two or three lines. "BT" emits an impulse before the total line is pringed. "AT" emits an extra impulse after the total line has been printed and is used in Tabular Form A to gain additional spacing prior to the printing of X and Y lines. (Both "AT" and "L" emit impulses between the total line and the printing of the X or Y line whichever card group comes first.) "AH" emits an impulse prior to the printing of the first data line after the heading line and is used to gain additional spacing at the top of the table.

7. Digit Emit (k-1, 1-10). Digit emit generates a full set of digits for each card cycle. It is normally wired to Line Control (for transfer of digital information to the Summary Punch), Duplicate Control (to force the counting of all cards), and Heading Control (to provide tabular identification information). Ten digits are available, and each may be obtained from either of two common hubs.

8. Heading Control (1, 11-20). Heading Control consists of three two-hub fields and a single three-hub field; provides entry into the heading line of the printed table; and may be used to transfer either arbitrary information or data from the first card of each primary group being processed to the Summary Punch. To print arbitrary information, wire to Heading Control from Digit Emit. To print from card fields, wire to Heading Control from Third Reading hubs. Heading Field 1 (H_1) prints on the heading line at Alphameric positions 2 and 3. Field 2 (H_2) prints at Alphameric positions 5 and 6. Field 3 (H_3) prints at Numeric positions 24 and 25. Field 4 (H_4) prints at Numeric positions 27, 28 and 29.

When Set-up Switch #2 is On, Heading Control Field 1 (H_1) may also be used to transfer additional information to the Summary Punch. Information to be transferred is read into Field 1 for every first card of a line group (instead of for the first tabular card only). This information may be taken from the card being processed (wire from Third Reading hubs) or wired arbitrarily from Digit Emit. The information is then available for each line of the table from Counter 2B. When so used Counter 2B cannot be used for counting cards punched X in the horizontal variable in its normal function, and short hammerlocks Numeric 18 and 19 (for Tabular Form A) or Numeric 12 and 13 (for Tabular Form B) should be raised to suppress printing of the information to be transferred upon the printed table. Should cards punched X in the horizontal variable be processed with Set-up Switch #2 on, they will be ignored (as far as frequency count is concerned) in Tabular Form A. In Form B they will be counted in line, column and grand totals even though direct data indication is missing. Information entered into H_1 with Set-up Switch #2 on will also appear in its usual field in the heading line. (With Set-up Switch #2 on, entry is provided for six columns of identity information to the Summary Punch which can be printed on each secondary card. With Set-up Switch #2 off, H_1 again reverts to its usual function, X's are once again counted normally, and four columns of identity information may be transferred to the Summary Punch - through Line Control.

9. (•) (1, 20). (•) is a single hub which accepts impulses from the Second Reading hubs only and which controls the spread of the horizontal variable across the table. It may be wired to any single-column field of the card. A card passing the Second Reading hubs emits an impulse through (•) which is used to set up the proper counting of that card at the Third Reading hubs.

10. Skip (k, 11-12). Skip is a two-hub switch which, if connected, causes a skipping impulse to go to the Tape-Controlled Carriage after the conclusion of one table and before the heading line of the following table is printed. This impulse is normally used to cause each table to appear at a chosen position upon a fresh page.

11. Overflow (k, 13-14). Overflow is a two-hub switch which, if connected, causes an avoidance of the last two or three lines of a tabular sheet and an automatic skipping to the proper heading location on a new page. Overflow must

be used in connection with Skip (although it need not be wired when Skip is wired), and an appropriate tape must be cut and inserted in the Carriage for either Skip or Overflow.

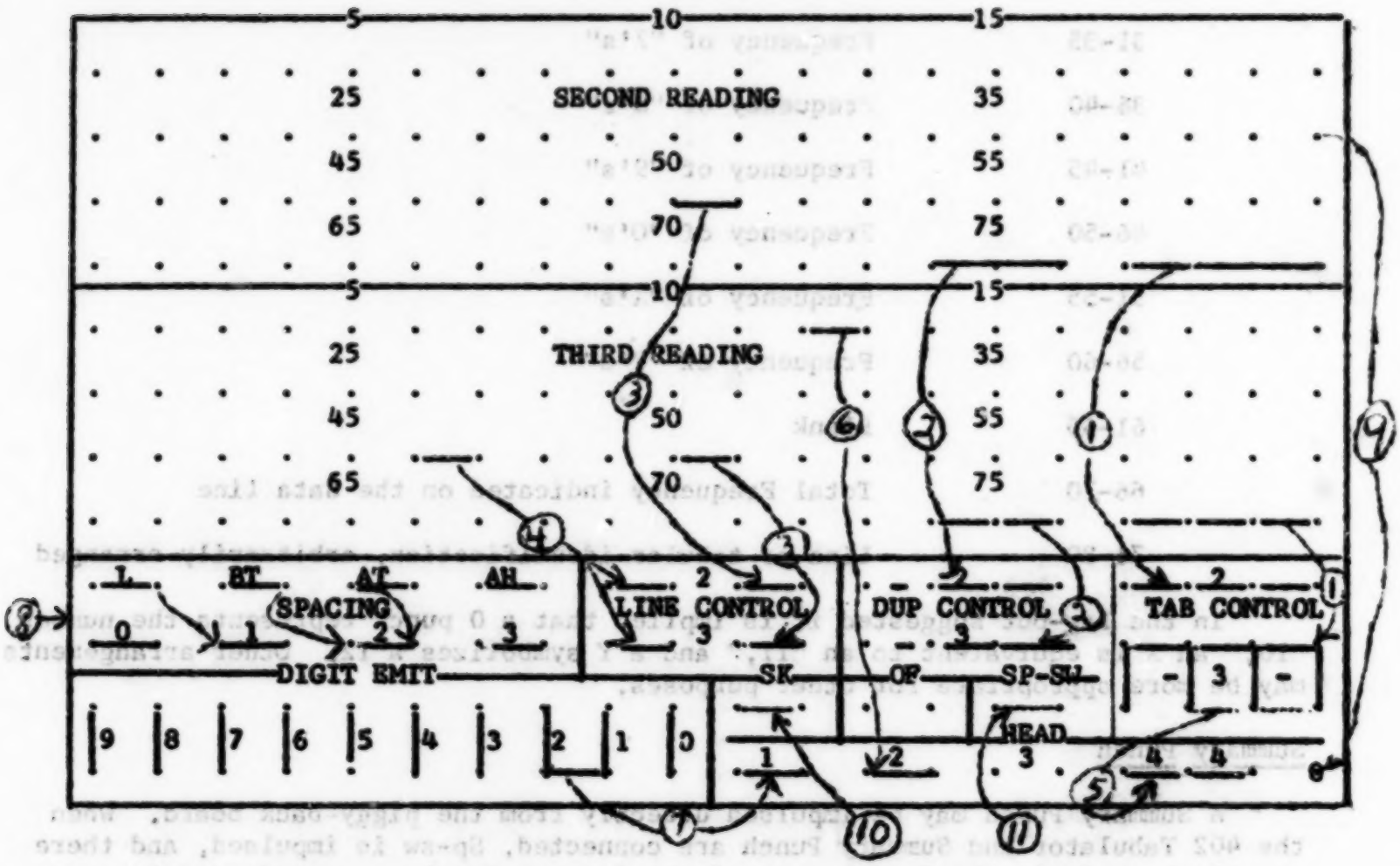
12. Sp-Sw (k, 15-16). Sp-sw is a two-hub switch which, if connected, causes the Summary Punch to operate and to duplicate on a card the information in a given tabular line. When Sp-sw is connected, secondary cards will be punched for all data lines including X and Y lines, but not for heading or total lines. An alternate wiring (within the standard 402 panel) will cause an additional card to be punched for total lines; but no card will be punched for the Heading Line. When Sp-sw is not connected, the 402 will operate as a simple tabulator and prepare tables without card duplication. Sp-sw is identical to the same switch on the standard 402 panel.

Figure 2.9 gives an example of a wired piggy-back panel. (1) Wiring goes from hubs 77 through 80 of Second and Third Reading hubs to corresponding rows of Tabular Control representing a four-column deck number field or any other field which is constant throughout the tabular deck. (2) A three column field, hubs 74 through 76 representing respondent number, is wired from Second and Third Reading hubs to Duplicate Control. Cards within a given line group which duplicate other cards in respondent number will be ignored. (3) Line groups are identified by wiring a two-column field from hubs 50 and 51 from Second and Third Reading to Line Control. This two-column field corresponds to the variable being spread along the vertical dimension of the table. When a new line group appears at the Second Reading hub, card reading will stop and a tabular line will print. (4) Two positions of line control are unused for line group discrimination and may be used for transfer of information to the Summary Punch. Wiring goes from columns 46 and 47 Third Reading hubs to the unused positions of Line Control, and each wire is split to present the same information to both rows of Line Control. (Short hammerlocks Alphameric 8 and 9 are raised to prevent printing of this information on the table.) (5) Three columns of the Tabular Control field are wired to H_4. (6) Two columns of information are wired from the card being read from Third Reading hubs 12 and 13 to H_2. (7) An arbitrary two-digit number, "21", is wired from Digit Emit into H_1. (This number is also available at the Summary Punch in Counter 2B if Set-up Switch #2 is on. However, no counting of X's will take place if Switch #2 is on.) (8) One space is wired for each data line, but "BT," "AT," and "AH" are each wired for two spaces. (9) The variable to be spread horizontally, represented by a single column field in column 40, is wired from Second Reading to (·). (10) Skip is wired to cause each table to print on a new page. (11) Sp-sw is wired to cause the punching of secondary cards at the Summary Punch.

Secondary Cards

Secondary cards representing lines of the printed table may be laid out in any appropriate arrangement of fields by appropriate wiring of the Summary Punch control panel. However, we have established for convenience a standard secondary card lay-out which is indicated directly below. It will be noted that all data fields of this suggested lay-out are five columns deep. When used with the described program these fields will obviously not show more than two, three, or four columns of significant digits. (See page 23)

Figure 2.9—Wired Piggy-back Control Panel



Field in Columns	Information Punched
1-5	Frequency of "1's" indicated on the data line
6-10	Frequency of "2's"
11-15	Frequency of "3's"
16-20	Frequency of "4's"
21-25	Frequency of "5's"
26-30	Frequency of "6's"
31-35	Frequency of "7's"
36-40	Frequency of "8's"
41-45	Frequency of "9's"
46-50	Frequency of "0's"
51-55	Frequency of "X's"
56-60	Frequency of "Y's"
61-65	Blank
66-70	Total Frequency indicated on the data line
71-80	Line or tabular identification, arbitrarily arranged

In the lay-out suggested it is implied that a 0 punch represents the number "10," an X is equivalent to an "11," and a Y symbolizes a 12. Other arrangements may be more appropriate for other purposes,

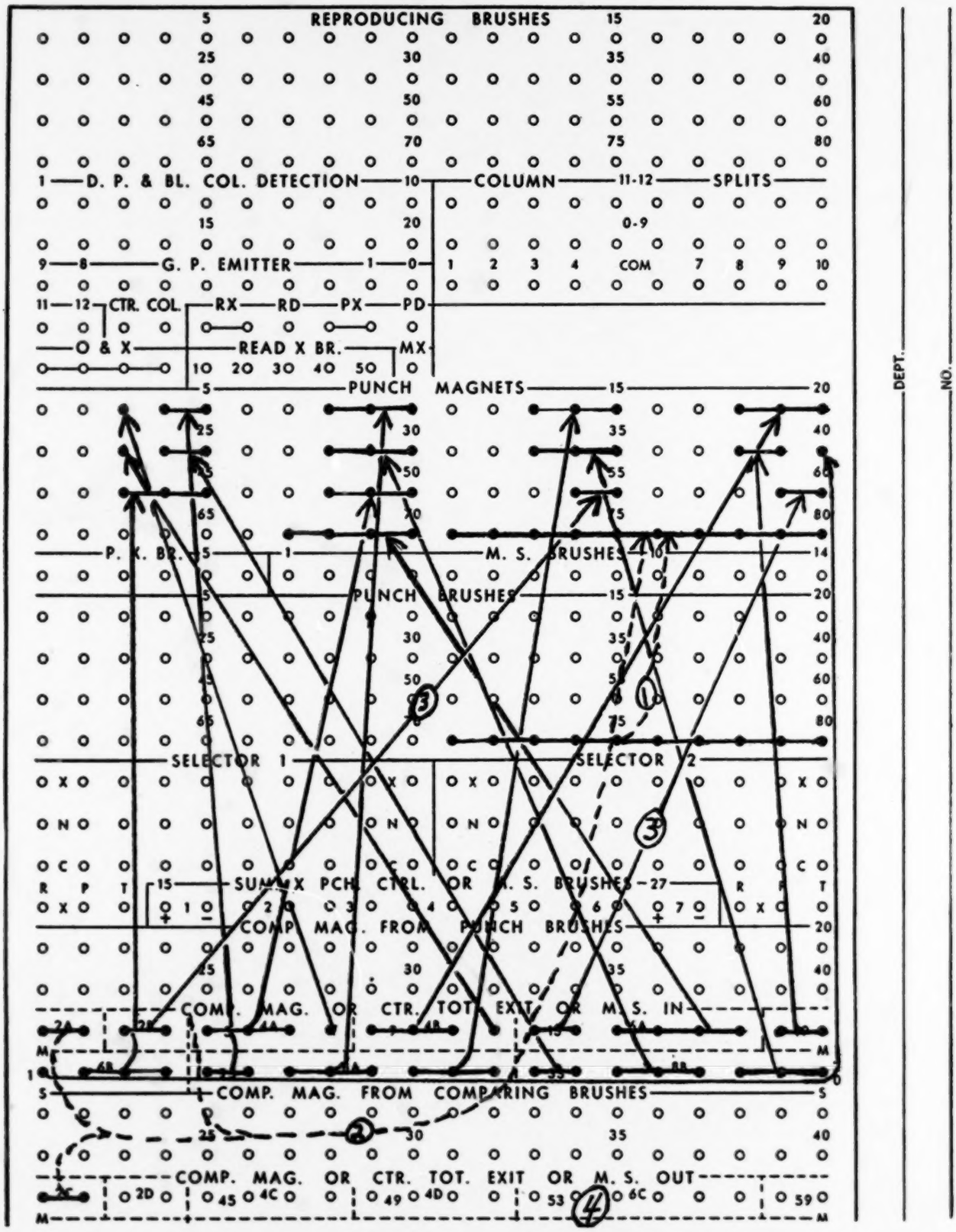
Summary Punch

A Summary Punch may be impulsed directly from the piggy-back board. When the 402 Tabulator and Summary Punch are connected, Sp-sw is impulsed, and there are blank cards in the feed hopper of the Summary Punch, a secondary data card will be punched for each data line of the table, including X and Y lines. Figure 2.10 shows a wiring diagram for the 514 Summary Punch which will give a secondary card lay-out as described above. Other Summary Punches may be wired similarly.

It should be noted that in Figure 2.10 frequency information is available from all A and B counters except 2A and 2B. Counters 2A and 2C are used for storing line identification information and are entered through Line Control. Counter 2B is used normally for the storage of X frequencies, although when Set-up Switch #2 is on it is connected to H_1 and may be used to transfer information to the Summary Punch. All other counter positions in A and B counters store frequencies exclusively. Figure 2.11 gives a general picture of the location of stored frequencies in counters, the Tabulator type bars at

Figure 2.10

WIRED 514 CONTROL PANEL



1. Information may be entered into columns of the Identification Field (Cols. 71-80) by gang-punching from a lead card. Wire those columns indicated from Punch Brushes.
2. Information for the Identification Field may also be taken from Counters 2A and 2C (and, when Set-up Switch #2 is On, from Counter 2B). Wire from these counter exits appropriately.
3. The X and Y fields should not be wired for Tabular Form A. Fields which should be empty (unless a primary card is read with a mistaken punch) should also be deleted.
4. Information may be read out of "C" and "D" counters should it be desired to punch cards corresponding to Total Lines. (Change 402 wiring appropriately.)

which each field is printed, and the columns in the secondary card at which each field is normally printed. The C and D counters are used for storage of frequencies which will be printed on the total line, and each counter is used identically with its A or B equivalent. (It should be noted that in order to utilize all counter positions, ties have been made between counters. Counters 4A and 8A, 4B and 8B, 4C and 8C, and 4D and 8D have all been tied.) If desired, secondary cards corresponding to the total line may be punched by changing wiring upon the standard 402 panel.

Columns 71 through 80 of the secondary card are slated for line and tabular identification data. Up to six columns of identification data may be passed to the Summary punch through Counters 2A, 2B and 2C; and these data may either be arbitrary digits generated at Digit Emit or may be read from the first card of the line group being processed. These six columns of identification may be entered at will into any of the ten columns available. It is also possible to enter additional information into the identification field by gang punching from a leading card. This is ordinarily done for an identifying deck number or other information which should be identical for all secondary cards. A lead card with the correct information is placed immediately ahead of the blank cards which are then fed through the Summary Punch. Information in the lead card is picked up at the Punch Brushes and brought back to punch in turn each following card of the Secondary Deck. Wiring in this case will go from the Punch Brush hubs to the Punch Magnet hubs.

Operating Instructions

The following steps must be performed in building a table from primary cards. Steps in parentheses will refer only to the reproduction of tables on secondary cards.

1. Sort cards. (a) For respondent number (if Duplicate Control is to be used). (b) For line groups using the vertical variable.

2. Wire the piggy pack panel. Line Control, Tabular Control and (•) must be wired. Wire Duplicate Control if only one card is to be counted for each respondent and more than one card per respondent is present in the deck. If not, wire a single digit to Duplicate Control to force counting of all cards. Wire Spacing and Heading Control as needed. Wire Skip and Overflow if indicated. (Wire Sp-sw.)

3. Install panel in the 402 Tabulator. Install forms tractor (or other appropriate platen equipment) and sheets of paper at least 11½ inches wide. Check settings of Set-up Switches #'s 1 and 2.

4. Raise Hammersplit levers: Alphameric - 3, 6, 11, 15, 19, 23, 27, 31, 35, 39, 43. Numeric - 3, 7, 21, 25, 29. If Tabular Form A is to be used, also raise Numeric Hammersplits 12, 13 and 17. If Form B, raise Numeric Hammersplits 11, 15 and 20.

5. Raise Short Hammerlocks: Alphameric - 1, 4, 7, 12. Numeric - 23, 26. Raise all Long Hammerlocks. Raise Alphameric short hammerlocks 8, 9 and 10 as needed to suppress unwanted zero or information printing out of Line Control. Raise Short

Figure 2.11—General Program - Location of Tabular Information

Tabular Column	Counter Position	402 Type Bars	514 Punch Columns
0	4A-8A(L)**	13-14-15 Alph	48-49-50
1	4A-8A(LC)	17-18-19 Alph	3-4-5
2	4A-8A(RC)	21-22-23 Alph	8-9-10
3	4A-8A(R)	25-26-27 Alph	13-14-15
4	4B-8B(L)	29-30-31 Alph	18-19-20
5	4B-8B(LC)	33-34-35 Alph	23-24-25
6	4B-8B(RC)	37-38-39 Alph	28-29-30
7	4B-8B(R)	41-42-43 Alph	33-34-35
8	6B(L)	1-2-3- Num	38-29-40
9	6B(R)	5-6-7 Num	43-44-45
T	6A(R)	9-10-11-12 Num,* or 17-18-19-20 Num	67-68-69-70
X	2B	16-17 Num,* or 10-11 Num	54-55***
Y	6A(L)	20-21 Num,* or 14-15 Num	59-60***
Row Indication	2C (Low order) 2A (Hi order)	8-9-10-11 Alph	
Tab. Indication	None (Co-selectors 5. and 6. Transferred	2-3, 5-6 Alph, 24-25, 27-28 Num.	71 thru 80 (any order--either from 2A,2B,2C or from gang-punching

*First type bars listed, Tabular Form A. Second type bars listed Tabular Form B.

**Counter numbers given are only for the top row. "1," for instance, is stored in 4A-8A(LC) for line printing and 4C-8C(LC) for total row printing. Similar rules apply to all other columns.

***These columns are not to be punched when making cards from Tabular Form A.

Hammerlocks Alphameric 2, 3, 5, 6 and Numeric 24, 25, 27, 28, 29 as needed to block printing of unwanted Heading information.

6. (Attach 402 to the Summary Punch by means of the connecting cord provided. Turn Summary Punch on. Switch off reproducing functions if any. Punch appropriate lead card for gang punching information into the secondary card deck (if any), and install it on top of the deck of blank secondary cards. Insert the deck of blank secondary cards in the feed hopper face down and Y edge towards the machine. (For duplicating Summary Punches, make certain that cards are inserted into the punching hopper). Press the Feed button.)

7. Turn 402 On. Press Start and Final Total simultaneously twice. This forces a clearing of all counters and prints the result. Adjust the paper sheet for desired first line of printing. Install and adjust spacing tape in its mechanism. Insert sorted cards in hopper face down and nine edge towards the machine. Depress start button.

LIMITATIONS:

The following is a summary of limitations inherent in this program.

1. The maximum frequencies which can be tabulated in each category of the table are limited by the number of counter positions available. In general, no tabular entry nor column total can exceed 999. No X or Y tabular entry nor X or Y column total can exceed 99. No Line Total nor Grand Total can exceed 9999. If these restrictions are not met, overflow from counter positions will in some cases appear as digits in other columns and will in other cases simply be lost. The following listing of overflow locations is derived from Figure 2.11.

Overflow Digits from	Appear in the units position of
"1" - (Alph 17-18-19)	"0" - (Alph 13-14-15)
"2" - (Alph 21-22-23)	"1" - (Alph 17-18-19)
"3" - (Alph 25-26-27)	"2" - (Alph 21-22-23)
"4" - (Alph 29-30-31)	Lost
"5" - (Alph 33-34-35)	"4" - (Alph 29-30-31)
"6" - (Alph 37-38-39)	"5" - (Alph 33-34-35)
"7" - (Alph 41-42-43)	"6" - (Alph 37-38-39)
"8" - (Num 1-2-3)	Lost
"9" - (Num 5-6-7)	"8" - (Num 1-2-3)
"0" - (Alph 13-14-15)	Lost
"X" - (Num 16-17 "A," 10-11 "B")	Lost
"Y" - (Num 20-21 "A," 14-15 "B")	Lost
Total - (Num 9-10-11-12 "A," 17-18-19-20 "B")	"Y" - (Num 20-21 "A," 14-15 "B")

2. A number of limitations may be placed upon piggy-back board wiring. These spring from the various functions of the Pilot Selectors, Co-Selectors, Digit Selectors, and Comparing positions used in wiring the 402 panel. A Summary of these functions is given in Figure 2.12. Among the wiring limitations are the following: (a) Tabular Control must always be wired to initiate the end of the table. (b) Duplicate Control must always be wired, either from cards or from Digit Emit. (c) (•) must always be wired from the Second Reading hubs. (d) Overflow cannot be used unless Skip is also in use.

3. Heading identification fields and the line identification field are programmed to print zeros if not impulsed with digits. To suppress zero printing, short hammerlocks must be raised. Y columns and lines are not identified with any symbol. (On the other hand, they are the only data units not so identified. X columns and lines are identified with an asterisk.) Total columns and lines are not identified except for an asterisk printed immediately behind the Grand Total.

4. If it is desired to utilize secondary cards for direct computer input, editing of the cards may be indicated. Prior editing includes the non-punching of those fields into the secondary cards which "should not contain data." For instance, in Tabular Form A, ordinarily X and Y are not meaningful data and should not be entered into the secondary cards (where they will be read in certain computer programs as "number of 11's" and "number of 12's"). Delete wiring (3) in Figure 2.10. Similarly, if processing responses which are scaled in terms of five possible answers, any codes of "7" (which will appear in the "7" column of the table) should ordinarily not be punched onto secondary cards. In order to protect the cards, delete the Summary Punch wiring of those fields which "should" be empty. The hand editing of mistaken cards may also be necessary in those cases where, for instance, card feed was sufficiently interrupted so that the 402 broke apart line groups, interpreted the end of a table, etc.

5. The vertical variable is limited to a four-column field, hence there can be no more than 10,000 line groups in a single table (plus X and Y line groups of which only two may be unequivocally identified). The horizontal variable is limited to a single-column field; hence, there can be no more than ten columns plus X and Y.

6. For certain types of computer programs, scaled data must be entered as the horizontal variable while respondent or response groups or categories must form the vertical dimension. This restricts the length of scales which may use this program to 12 categories or less.

7. The use of Tabular Forms A and B is invariant. One cannot, for instance, include the counting of X's within the table and exclude Y's. Similarly, when Set-up Switch #2 is on, X's are not counted, while Y's continue to be counted. Other arrangements are not possible.

8. No more than six digits of information may be transferred from the Tabulator to the Summary Punch, and the last two digits are transferred at the cost of counting X's. Any other identification information desired on the Secondary Cards must be gang punched from (if necessary several) lead cards.

9. On the horizontal variable, blank cards are interpreted as if they were punched "Y." On the vertical variable, blank cards may be sorted to form a distinct line group, but the group indication will be indistinguishable from the "0000" group which will be tabulated on a separate line.

Figure 2.12—Tabular Functions

Control Unit	Initiation of Function	Controls
Selectors 1-11	Transfers one card cycle following appearance of selected digit at second reading brushes and remains transferred for one card cycle	(a) When transferred, sends a "1" impulse to correct counter. When not transferred, "1" impulse goes to next selector so that no double counting of cards is possible. (b) When transferred, sends a "1" impulse to total counter. When not transferred, "1" goes to next selector.
Selector 12	Transfers one card cycle following appearance of an X or Y card in the units position of the line identification field at the second reading brushes, but on Tabular Form A only	(a) When normal, sends a comparing impulse to Intermediate Program Start thus providing a total line and At spacing for Tabular Form A. When transferred, comparing impulse goes to Minor Program Start providing normal group indication for both X and Y cards (b) When transferred, allows a card cycles impulse to pick up Selector 16, which transfers one cycle later.
Selector 13	Transfers when an X card in the units position of the line identification field is not passing the third reading brushes	When normal, sends an "s" impulse (through Co-Selector 10) to print at Numerical 25 on Minor Program Cycles to indicate X cards.
Selector 14	Transfers when card following is <u>not</u> a duplicate in terms of respondent number	Operates with Co-Selector 6 to control counting of duplicate cards. When transferred, allows a card count to proceed to counters. When normal, allows a card count impulse to pass only if Co-Selector 6 is transferred; i.e., if the card being read is the first card of a new minor group.
Selector 15	Picks up one cycle after First Card Major (through Co-Selector 5), thereafter holds itself transferred (through Co-Selector 6) until the following First Card Minor is completed.	(a) When transferred, provides a channel for a card count impulse (from Co-Selector 6) to hold itself transferred. When normal, no channel is provided. (b) When normal, provides a Minor Total impulse for line spacing. When transferred, the same impulse is used for AH spacing.

Control Unit	Initiation of Function	Controls
Selector 16	Transfers one cycle following the appearance of either an X or Y card in the units position of the line identification field at the third reading brushes and remains transferred until First Card Major, but on Tabular Form A only	When transferred, suppresses the printing of intermediate Totals (which would provide a total line for X and Y lines in Tabular Form A) by impulsing I Hammerlocks
Co-Selector 1	First Card Intermediate	(a) Takes an All Cycles impulse (through Co-Selector 6) for each minor total cycle. When transferred, this impulse is available for BT spacing. When normal, the impulse is used to suppress printing on all first card minor cycles not either intermediate or major. (b) When normal, allows printing of row indication. When transferred, printing in the row indication field is suppressed.
Co-Selector 2 3 4	Set-up Change Switch #1.	(a) Controls tabular arrangements of X, Y and Total Fields for Tabular Forms A (Normal) and B (Transferred).
Control Unit	Initiation of Function	
Selector 16	Transfers one cycle following the appearance of either an X or Y card in the units position of the line identification field at the third reading brushes and remains transferred until First Card Major, but on Tabular Form A only	(b) When transferred, allows entry of X and Y card counts into the Total Counter (for Tabular Form B).
Co-Selector 5	First Card Major	(a) Distributes digit impulses to short-hammerlocked type bars to force zeroes on subsequent printing positions. When normal, impulses go to Numerical 7 (forces 0's in the row identification number). When transferred, impulses go to Numerical 1, 4 and 12 and Alphamerical 23 and 26. (b) Prevents printing of "1" impulses entering X and Total Counters on First Card Major cycle (when a print cycle is taken to print the heading line). When normal, allows printing to take place. (First card minor cycles do not print. First card intermediate cycles are hammerlocked.) (c) When transferred, utilizes a card count impulse to pick up Selector 15. (See Selector 15.)

Control Unit	Initiation of Function	Controls
Co-Selector 5	First Card Major	(d) When normal, allows a First Card Intermediate impulse to cause both counter exit suppression and listing. (This takes place on only the first card cycle following the Intermediate Total which prints the total line in Tabular Form A.)
Co-Selector 6	First Card Minor	(a) When transferred, prevents printing of "1" impulses entering X Counters on First Card Minor cycles (useful only on First Card Major when an unencumbered print cycle is taken), and allows the printing of an "*" to identify the X column. When normal, allows normal printing from X counters. (b) When transferred, sends an All Cycles impulse to Co-Selector 1. (See Co-Selector 1.) (c) When transferred, allows a card count impulse to proceed to Selector 14, thus allowing the counting of <u>all</u> cards (regardless of status as duplicates in respondent number field) when they are first cards minor. (See Selector 14.) (d) When normal, sends a card count impulse to hold in Selector 15. When transferred (or on all total cycles), no holding impulse proceeds to Selector 15. (See Selector 15.)
Co-Selector 7 8 9 10	First Card Major	(a) When normal, allows printing from the low-order position of all numerical counters. When transferred prevents the printing of "1's" entering these counters and instead allows the printing of columnar identification numbers. (b) When transferred, allows the printing of tabular identification fields. When normal, the printing of tabular identification is suppressed. (c) When normal, allows the printing of an "*" to identify totals for X Cards (see Selector 13).

Control Unit	Initiation of Function	Controls
Co-Selector 11	Set-up Change Switch #2	(a) When transferred, allows material being entered into H_1 to also enter Counter 2B. When normal, Counter 2D (low-order position) is connected to 2B so that normal counting of "1's" for X's may take place normally.
		(b) When normal, Counter 2B is impulsed to add upon each card cycle, thus counting X cards. When transferred, Counter 2B adds only upon First Card Minor, thus picking up information entered into H_1 for the first card of each line group.
Co-Selector 12	Set-up Change Switch #1	When normal, sends the incoming impulses from the low-order position of Line Control to Column Split, thus allowing a differentiation of X and Y cards from data cards for Tabular Form A. When transferred, the same impulses go directly to the Comparing Entry fields for Tabular Form B

CHAPTER III

A COMPUTER PROGRAM FOR THE MANN-WHITNEY z_U WITH TIED RANKS

PURPOSES: (a) To form a table of two lines and m columns by selecting and combining rows from an n by m contingency display.

(b) To compute for this table the normal deviate z_U.

(c) To compute the weighted means $\bar{X}_A$ and $\bar{X}_B$, for each line of this table.

GENERAL METHOD AND RANGE: Input for this program is in the form of an n by m ($n \leq 99$, $m \leq 12$) rectangular matrix which is a contingency table; i.e., each entry in the table is a frequency of occurrences (see Figure 1). This input table may be completely prepared (in card form) by a tabulator-summary punch from primary data cards.

Output for the program is in the form of a series of 2 by m contingency tables drawn independently as desired from the input table with z_U, $\bar{X}_A$ and $\bar{X}_B$ computed for each output table (see figure 2). The following equations are used:

$$z_U = \frac{T_A\,(T+1) - 2\,R_A}{\sqrt{\frac{T_A T_B}{3}\left[T\,1 - \frac{\sum_{i=1}^{m}\,(T_i^3 - T_i)}{T\,(T-1)}\right]}}$$

T_A, T_B, T, T_i - row, table and column totals (see Figure 2).

R_A = sum of the ranks for row A = $\sum_{i=1}^{m} x_{Ai}\,Md_i$, where Md_i is the median rank of all items in column i of the output table.

$$\bar{X}_A = \frac{\sum_{i=1}^{m}\,(x_{Ai}\;i)}{T_A} \qquad \bar{X}_B = \frac{\sum_{i=1}^{m}\,(x_{Bi}\;i)}{T_B}$$

i - column number or weight

x_{Ai}, x_{Bi} - frequencies of output table.

MANN-WHITNEY U TEST: The Mann-Whitney U is a non-parametric statistic having essentially the same function as a "t" test for difference between two sample means. U tests the null hypothesis that two sample distributions are insignificantly different against the signed hypothesis that the central rank tendency of one sample is greater than the central rank tendency of another sample. When sufficiently

large samples are used (T_A and T_B are both greater than 8), z_U is normally distributed. For small samples, tables exist giving exact probabilities for U; and a modified form of these tables for z_U to be used in conjunction with this program may be obtained. Z_U is essentially free of the distributional form of the two samples, makes use only of ordinal information, can be used as either a one - or two-tailed statistic, and has a power exceeding 95% of "t" for large T's.

PROGRAM OPTIONS:

1. Up to 800 different 2 by m output tables may be prepared from each input table. Both line A and line B of the output table may be formed by summing any of the 99 rows of the input table. Any combination of rows may be selected as long as the total number of rows selected for both lines A and B does not exceed 92 for any one output table. The output row identification, however, is limited to displaying correctly only the first 27 rows chosen for each line.
2. After line B has been formed it may be inverted for any group of output tables, and all calculations are then made using the inverted line.
3. The input table may be in the form of cards (normal) or paper tape. If entry is paper tape the combining feature (option 1) may be omitted.
4. Output tables may be punched into cards (normal) or printed on the IBM 402 on line printer.

GENERAL PROGRAM METHOD:

This program is entirely in fixed point. Data are packed two entries (table columns) per ten digit computer word. Burroughs Fixed Point Square Root Subroutine 2.20.010 is incorporated and stored in locations 1260-1285. The total program is divided into separate sections as follows:

1. Card Read
2. Write the vertical condenser (combining program)
3. Condenser Program
4. Invert line B
5. Calculate z_U, $\bar{X}_A$, and $\bar{X}_B$
6. Card Write

The basic program read into the computer skips section 4 and an address must be changed if it is desired to invert line B before calculations. If paper tape input is desired without combining or inverting, the program can be entered just prior to section 5. (See Data Preparation for Paper Tape Input)

There is a short "Speed-Up" routine which can be used before the first input table is read in if $M \leq 10$ which enables the computer to omit calculations on empty columns. Key addresses in the program are set on the basis of the maximum number of columns of data in the output table. (See Selection Tape Preparation and Fig. 3.9)

Also incorporated on the program tape are program changes which can be read in to enable the program to handle correctly output tables of T > 316. (See Limitations and Fig. 3.9)

CARD LAYOUT:

Input: Input cards are in a standard format and can be prepared automatically from a summary punch which is reading a tabulated contingency table. See Figures 3.3 and 3.4. One input card represents each row of the input table. Row identification is given by a two-digit field, normally wired in by control panel wiring as columns 79-80. Input cards for each table must be sorted into ascending order by row number. A given final row numbered card, which indicates the end of an input table and initiates the rest of the program, must be last for each input table.

Output: Output tables are punched into a four to six card set. Cards 1, 2, and 3 are always punched for each output table and include the table, $\bar{X}_A$, $\bar{X}_B$, z_U, table identification, and combining information (see Figures 3.5 and 3.6. If the combining information for either line of the output table is more than one word (3 row identification numbers) in length, then cards 4, 5, or both are punched with combining information. The last card, except when more than 27 rows are combined to form line B, of each table is punched with zeroes. Print out directly on the on-line printer is identical with the above description except that the lines are printed making provision for indication of a negative word with each 10 digits.

Figure 3.1--Input Table

($m \leq 12$, $n __ 99$)

COLUMN

ROW	1	2 . . .	i . . .	m	
1.	x_{11}	x_{12} . . .	x_{1i} . . .	x_{1m}	T_{1i} $(= \sum_{i=1}^{m} x_{1i})$
2.	x_{21}	x_{22} . . .	x_{2i} . . .	x_{2m}	
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	
j	x_{j1}	x_{j2} . . .	x_{ji} . . .	x_{jm}	T_{ji} $(= \sum_{i=1}^{m} x_{ji})$
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	
n	x_{n1}	x_{n2} . . .	x_{ni} . . .	x_{nm}	T_{ni} $(= \sum_{i=1}^{m} x_{ni})$
	T_{j1} $(= \sum_{j=1}^{n} x_{j1})$		T_{ji} $(= \sum_{j=1}^{n} x_{ji})$	T_{jm} $(= \sum_{j=1}^{n} x_{jm})$	T_{nm} $(= \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ji})$

Figure 3.2--Output Table

($m \leq 12$)

COLUMN

LINE	1	2 . . .	i . . .	m	
A	x_{A1}	x_{A2} . . .	x_{Ai} . . .	x_{Am}	T_A $(= \sum_{i=1}^{m} x_{Ai})$
B	x_{B1}	x_{B2} . . .	x_{Bi} . . .	x_{Bm}	T_B $(= \sum_{i=1}^{m} x_{Bi})$
	T_1 $(= x_{A1} + x_{B1})$		T_i $(= x_{Ai} + x_{Bi})$	T_m $(= x_{Am} + x_{Bm})$	$T = T_A + T_B$

Figure 3.3--Input Format as Read Into Computer[1]

CARD COLUMN	1 - 5	6 - 10	11 - 15	16 - 20	...	66 - 70	71 - 78	79 - 80
DATA	x_{j1}	x_{j2}	x_{j3}	x_{j4}		T_j [2.]	Table No. [3.]	Row No.

1. Can be varied by control panel wiring especially in last 10 columns to give versatility in determining row number.

2. Can be omitted or changed; not used by the program.

3. Can be omitted; only serves to identify output tables.

Figure 3.4--Sample Input Table of 10 Cards

	CARD COLUMNS						
	4,5	9,10	14,15	20	25	71 - 78	79 - 80
CARD 1	4	4	5	0	0	12345678	10
2	25	2	2	0	1	12345678	11
3	38	15	13	1	3	12345678	12
4	25	22	14	4	1	12345678	13
5	1	1	1	1	0	12345678	14
6	3	2	0	0	0	12345678	15
7	5	2	1	0	0	12345678	16
8	5	0	1	0	0	12345678	17
9	9	4	3	1	1	12345678	18
10	5	0	3	0	0	12345678	19

Figure 3.5--Output Format

CARD	COLUMNS						
	1 - 5	6 - 10	11 - 15	16 - 20 ... 61 - 65	66 - 70	71 - 80	
1.	x_{A1}	x_{A2}	x_{A3}	x_{A4} $\bar{X}_A$ [1.]	T_A	COA_1A_1 ... [2.]	
2.	x_{B1}	x_{B2}	x_{B3}	x_{B4} $\bar{X}_B$ [1.]	T_B	COB_1B_1 ... [2.]	
3.	T_1	T_2	T_3	T_4 s_U [1.]	T	Table# Row# [3.]	

4. zero card or combining information for line A.

5. zero card or combining information for line B.

6. zero card or excess combining information for line B.

1. Expressed as 2 whole numbers and 3 decimal digits properly rounded.

2. First or only word (3 or fewer row numbers) of combining selection information for this line of table (See Selection Tape Prep.)

3. Row number (from first row of the input table.)

4. Zero card is last card of normal output.

   (a) If combining information for each line is only one word long--card 4 is all zeros.

   (b) If combining information for line A is more than one word long and for line B is only one word long, then card 5 is all zeros.

   (c) If combining information for line B is more than one word long and less than 10 words, regardless of combining information for line A, card 6 is all zeros.

   (d) If combining information for line B is more than 9 words long, the excess is punched in card 6 and no zero card follows.

NOTE: All columns not otherwise punched will be punched with zeros. A negative word (i.e. group of 10 columns) is indicated with an 11 or X punch in the first column of the word (i.e. column 1, 11, ... 71.)

Figure 3.6--Sample Output From Sample Input Figure 3.4-- Using Combining Instructions From Figure 3.8

COLUMNS

	5	10	15	20	25	30 60	65	70	75	80
1.	25	2	2		1		1333	30	110	
2.	38	15	13	1	3		1800	70	120	
3.	63	17	15	1	4		2590	100	1234567810	
4.	Blank (all zeros)									
1.	25	2	2		1		1333	30	110	
2.	18	8	11	1	1		1949	39	10018019	
3.	43	10	13	1	2		3001	69	1234567810	
4.	Blank (all zeros)									
1.	102	44	32	6	5		1772	189	11012013*	
2.	18	8	11	1	1		1949	39	10018019	
3.	120	52	43	7	6		1091	228	1234567810	
4.	140150 16*	170								
5.	Blank (all zeros)									

*Is a negative word

SELECTION TAPE PREPARATION

All decisions of options desired and/or combinations required of an input table are controlled by one selection tape.

For the selection of the rows to combine and test for each output table, a program is written from selection information stored, beginning at 1600 in the following manner.

A word is divided into 3 sections of 4, 3, 3, digits each and row numbers to be combined for one line are packed three to a word.

If one, two or three rows form each line the information would be entered thus:

4 0 0 0 0 0 0 1 6 0 0

0 0 A_1A_1 0 A_2 A_2 0 A_3A_3

0 0 B_1B_1 0 B_2 B_2 0 B_3B_3

9 0 0 0 0 0 0 0 0 0

where A_iA_i is the 2 digit row number of the i^{th} row to be combined to form line A and B_iB_i is the i^{th} row to combine for line B. i = 1, 2, 3.

The last word (9000 00 0000) is to indicate that all information for selection for this output table is complete.

Instructions for the next output table from the same input table can be stored immediately after the 9000 00 0000 of a preceeding set of instructions. (See Figures 3.7 and 3.8.

If more than three rows are to be combined, all selection words for that combination except the last one are negative. Assume that r rows are to be combined to form line A and s rows to form line B. The selection tape would be:

1	0 0	A_1	A_1	0	A_2	A_2	0	A_3	A_3
1	. . .								
1	0 0	A_i	A_i	0	A_{i+1}	A_{i+1}	0	A_{i+2}	A_{i+2}
1	. . .								
	0 0	A_{r-1}	A_{r-1}	0	A_r	A_r	0	0	0
1	0 0	B_1	B_1	0	B_2	B_2	0	B_3	B_3
1	. . .								
1	0 0	B_s	B_s	0	0	0	0	0	0
	9 0 0	0	0	0	0	0	0	0	0

After the 9000 00 0000 of the selection set for the last output table for any given input table a 11000 00 0000 (negative 1000 00 0000) must be included as an indication to read a new input table.

If it is desired to invert a set number of columns of line B of the output table for a series of combinations or rows, this can be done by including the following commands on the selection tape:

```
4 0 0 0 0    0 0    1 4 7 5
  0 0 0 0    0 0    0 0 N N

4 0 0 0 0    0 0    1 0 5 9
  0 0 0 0    3 0    1 4 6 0
```

NN is the number of columns to be inverted.

When card input is used, each selection tape must contain instructions to store in location 1457 the number which is 6 times the row number of the last row in the input table. The instructions for this are:

```
4 0 0 0 0    0 0    1 4 5 7
0 0 0 0 0    0 0    0 L L L
```

where L L L is this number.

If paper tape input is used omitting the combining feature, the following program change is necessary:

```
4 0 0 0 0    0 0    1 3 8 4
  0 0 0 0    0 0    0 0 0 0
```

If paper tape input with combining is used, the following change is needed:

```
4 0 0 0 0    0 0    1 0 0 8
  0 0 0 0    0 0    0 0 0 0
```

For preparation of the data tape see Data Preparation for Paper Tape Input.

If the speed up routine is used the maximum number of columns KK in any output table must be stored in 0039 by the following instructions on the paper tape:

```
4 0 0 0 0    0 0    0 0 3 9
  0 0 0 0    0 0    0 0 K K
```

The order in which this information is placed on the selection tape is insignificant so long as all the orders of any one category are grouped together.

NOTE: A computer word is 10 digits preceeded by a sign digit. To enter data on the drum from paper tape it is necessary to preceed the data by a word with a 4 in the sign position and the first address where the data is to be stored in the four least significant digits of the word. (i.e., a 4 0000 00 1234 on the tape must preceed data to be read into storage beginning with drum location 1234). The digit 1 in the sign position makes a word negative. A word with a 6 in the sign position and an 8 in the sixth digit position (i.e., 6 0000 08 0000) is necessary at the end of the tape to stop its reading by the optical reader on the computer.

DATA PREPARATION FOR PAPER TAPE INPUT

If paper tape input is desired without any combining of rows for output, (i.e., output table equals input table) the first line of data is stored by packing 2 table columns per word in locations 5000 to 5005. The second line is stored similarly in locations 5008-5013. If desired, a table number may also be stored in location 1043. The data tape for each table ends with a 6 0000 30 1040. There should be about 18 inches of blank tape between data sections, and after the last data section before a 6 0000 08 0000. For the first set of data only, it is necessary to fill with zeros all unused columns after every table.

For paper tape input using the combining option, each data section of six words is stored beginning with the address which is 6 times its row number, i.e., if row number is 12, store the data in location 0072. Up to 99 rows can be entered and referred to for combining purposes with this input form. Each tape section should end with 6 0000 30 1440 followed by about 18 inches of blank tape. The data for any new table must be complete in replacing any previous data that is referred to. This may sometimes require filling locations with zeros. A 6 0000 08 0000 is required on the tape after the tape feed after the last table. Selection information must be included on the selection tape.

(Operating Instructions are given in Figure 3.9)

Figure 3.7--Selection Tape Summary

	ORDERS			PURPOSE
4	0 0 0 0	0 0	1 6 0 0	
	0 0 A_1A_1	0 A_2	$A_2$0 A_3A_3	First Output Table
	0 0 B_1B_1	0 B_2	$B_2$0 B_3B_3	
	9 0 0 0	0 0	0 0 0 0	
1	0 0 A_1A_1	0 A_2	$A_2$0 A_3A_3	These orders determine which rows of the input table are to be combined with each other to form the output table. They must be included for every case except non-combining paper tape entry.
1	. . .			
	0 0 A_rA_r	0 0	0 0 0 0	
1	0 0 B_1B_1	0 B_2	$B_2$0 B_3B_3	Following Table
1	. . .			
	0 0 B_{s-1}	B_{s-1}0	B_sB_s0 0$_s$0$_s$	
	9 0 0 0	0 0	0 0 0 0	
. . . .				
. . . .				
. . . .				
	9 0 0 0	0 0	0 0 0 0	End of last Table
1	1 0 0 0	0 0	0 0 0 0	End of Selection Commands
4	0 0 0 0	0 0	1 4 7 5	NN =
	0 0 0 0	0 0	0 0 N N	Number of columns to invert
4	0 0 0 0	0 0	1 0 5 9	These orders are necessary if line B is to be inverted before computation.
	0 0 0 0	3 0	1 4 6 0	
4	0 0 0 0	0 0	1 4 5 7	LLL =
	0 0 0 0	0 0	0 L L L	6 times last row no. of table
				These orders stop reading of an input table and are necessary if card read is used.
4	0 0 0 0	0 0	1 3 8 4	This change is needed for non-combining paper tape input.
	0 0 0 0	0 0	0 0 0 0	
4	0 0 0 0	0 0	1 0 0 8	This is necessary for paper tape input with combining.
	0 0 0 0	0 0	0 0 0 0	

Figure 3.7 (Cont)

4	0 0 0 0	0 0	0 0 3 9	KK = maximum number of columns in any output table. This is needed if speed up routine is used.
	0 0 0 0	0 0	0 0 K K	
6	0 0 0 0	0 8	0 0 0 0	This must be at the end of any selection tape.

Figure 3.8--Sample Section Tape

It is desired to read the cards given in Figure 3.4 not to invert line B, and to obtain three output tables.

1. row 11 vs. row 12
2. row 11 vs. rows 10, 18, 19
3. rows 11, 12, 13, 14, 15, 16, 17 vs. rows 10, 18, 19.

The speed up routine will be used for efficiency. The selection tape for this is:

```
4  0000  00  1600
   0011  00  0000
   0012  00  0000
   9000  00  0000
   0011  00  0000
   0010  01  8019
   9000  00  0000
1  0011  01  2013
1  0014  01  5016
   0017  00  0000
   0010  01  8019
   9000  00  0000
1  1000  00  0000
4  0000  00  1457
   0000  00  0114

4  0000  00  0039
   0000  00  0005
6  0000  08  0000
```

Figure 3.9--Operating Instructions

528

1. Make sure the 528 is set up correctly to read and punch (if card output is used).
2. Put the properly sorted cards in the read hopper and start the 528.
3. On the Model 500 Converter set cards in at 8, and cards out at 8.

402 (If direct output is desired)

1. Make sure the 402 is set up correctly to print from the computer.
2. Raise the following hammersplits
   Alphameric 5, 10, 11, 16, 21, 22, 27, 32, 33, 38, 43
   Numeric 1, 6, 11, 12, 17, 22, 23, 28, 33, 34, 39, 44

AT THE CONSOLE (Do all steps in order as they relate)

1. Read in the program tape. It stops after a sum check with 08 4444 in the C register.

   (a) Stop and clear if all T $\leq$ 316.
   (b) If T for any tables is likely to be greater than 316, read in rest of program tape. It stops with 08 6666. Stop and clear.

   If at any time on reading in, it stops with 08 9669 in the C register, re-read the whole tape in.

2. Read in selection tape. It stops with 08 0000. Stop and clear and turn input switch to keyboard. Push Step button.

   (a) If speed up routine is to be used, enter 6 0000 30 0020 F on keyboard and continuous. It stops with 08 1111.
   (b) If paper tape read with selection is to be used:

      1. Set breakpoint switch at 2.
      2. Enter on keyboard 6 0000 30 1000 F.
      3. Continuous.
      4. It stops with 34 1440
      5. Stop and clear

3. For Card Input - Start program with 6 0000 30 1000. It will run until stopped. (See section on TO STOP)

4. For paper tape input - start by reading in the tape. It will automatically call paper tape until the program is finished.

TO STOP

Tape input is self stopping. For card input there are two basic ways to stop the program.

1. Let it stop on a card read order (44 8000) when it runs out of cards in the 528. If this is done, it is necessary to have two blank cards after the last table.

2. Stop computer and set breakpoint switch at 4. It will then stop at the end of the next output table with a 34 1120. (This method is convenient if the program is to be temporarily stored on magnetic tape.) It is then restarted with a 6 0000 30 1440 (when read from mag tape).

At the 528, remove the unread cards from the read hopper. Run the remaining cards out of the read hopper and place the last two in front of the deck of unread cards from the hopper. This is the deck to start with for the next run.

TO LIST CARDS: 402

1. Set up 402 to list
2. Raise hammersplits
   Alphameric 5, 10, 11, 16, 21, 22, 27, 32, 33, 38, 43
   Numeric 1, 6, 11, 12, 17, 22, 23, 28, 33, 34, 39, 44

Figure 3.10 - Program Sections and Storage Allocations

Speed Up	0020 - 0054
Card Read	1000 - 1039 1420 - 1439 1152 - 1155 1457.
Write Condenser Program	1440 - 1456 1044 - 1119
Condenser	0900 - On as needed
Invert	1460 - 1530
Test	1120 - 1149 1158 - 1259 1286 - 1311 1540 - 1559
Card Write	1360 - 1419 1312 - 1316
Paper Tape Non Condenser	1040 - 1043
Square Root Subroutine	1260 - 1285
Large Table Provision	1531 - 1539
Empty	1150 - 1151 1156 - 1157, 1159 1240 - 1241 1317 - 1319 1474, 1476 - 1477 1458 - 1459 1520 - 1530

PROGRAM LIMITATIONS

The program normally will handle all data such that no T_i of the output table may be greater than 316. It will also handle T_i greater than 316 in most cases if the corresponding x_{Ai} times its rank is less than 100,000. No error stop occurs if this restriction is violated. If there is a possibility that T_i will be too large, there is a short set of modifications at the end of the program tape which can be read in.

The program is limited also in that $\Sigma(t^3 - t)$ must be less than 10^{10}. The program stops on overflow with 12 5019 in the C register. If any single $t^3 - t$ is greater than 10^{10}, however, the machine will not recognize it and $\Sigma(t^3 - t)$ will be incorrect.

If $\bar{X}_A = \bar{X}_B$ no calculation is made for z_U.

The sum of the number of rows to combine for line A and the number of rows to combine for line B cannot exceed 92.

"Correct" print out does not occur if line B is composed of more than 27 input table rows. Any extra combining information for line B extends into the sixth card and it is no longer blank for legible reading of output tables. Any extra combining information for line A does not punch out.

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CHAPTER IV

TABLES OF SIGNIFICANCE FOR THE MANN-WHITNEY z_U FOR SMALL FREQUENCIES

The Problem

It has been shown by Mann and Whitney 1/ that the statistic, U, provides a non-parametric test of ordinal difference between two jointly-ranked distributions which is not dependent upon distributional form. U may be defined as either of the two statistics which satisfy the following equation:

$$U_n = nm + \frac{n(n+1)}{2} - R_n \qquad (4.1)$$

Where n = Total frequency of items in one distribution.

m = Total frequency of items in the other distribution.

R_n = Sum of ranks for the distribution whose total frequency was n.

Utilizing this definition, it may be easily shown that U_n and U_m are two numbers which have distinct values if and only if R_n and R_m are distinct, that the mean of U_n and $U_m = \frac{nm}{2}$, and that the more distant either U_n or U_m is from $\frac{nm}{2}$, the more significant is the differences between the mean ranks of the two distributions.

Moreover, it has also been shown by Mann and Whitney that the statistic z_U which may be defined as a linear function of U:

$$z_U = \frac{U - \frac{nm}{2}}{\sqrt{\frac{nm(n+m+1)}{12}}} \qquad (4.2)$$

has the form of a normal deviate, when n and m are sufficiently large. Because z_U is not a normal deviate for small values of n and m, and because z_U is considerably more difficult to compute by hand than U, Mann and Whitney present tables for the level of significance of any given value of U for various values of n and m where n and m are both ≤ 8.

1/ Mann, H. B., and Whitney, D. R., "On a Test of Whether One of Two Random Variables is Stochastically Larger than the Other," Annals of Mathematical Statistics, 18:50-60, 1947.

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numerical value and differ only in sign.) (2) The Auble tables are redundant in that all entries are duplicated so that entry may be made for $n > m$ or $m > n$ (except, of course, those entries for $n = m$). (3) Finally, the Auble tables list critical values for only one level of confidence per page, whereas in actual practice the researcher is attempting to judge a computed value for z_U against a variety of critical values representing various levels of confidence, and wishes to choose that level which best corresponds to his obtained value. Accordingly, the tables to be presented are laid out so that entry may be made and level of confidence assessed on a single page.

In the tables to follow, m is assumed to be the smaller total frequency, each of the 20 tables deals with a unique value for m, lines appear in each table for values of n where $m \leq n \leq 20$, and eight columns list critical values of z_U each corresponding to an indicated probability level for a one-tailed test.

Limitations

Two limitations are inherent in the use of these tables. (1) The Auble (and Mann-Whitney) tables were computed for integer values of U. Hence, critical values which are listed for z_U are based upon the assumptions of a stochastic variate and the impossibility of certain values of U appearing. For instance, if we should assume a distribution function for z_U, then there will exist a critical value for z_U for $n = m = 2$, even though that value is so large as to be logically unattainable with U stochastically defined. This is the reason why cells corresponding to small frequencies and low levels of probability are empty in the tables which follow.

(2) Siegel 4/ presents a modification formula for z_U to be used when there are ties (when two or more items are found at the same rank). He points out:

4/ Siegel, Sidney, op. cit.

> If the ties occur between two or more observations in the same group, the value of U is not affected. But if ties occur between two or more observations involving both groups, the value of U is affected. Although the effect is usually negligible, a correction for ties is available for use with the normal curve approximation which we employ for large samples.
>
> The effect of tied ranks is to change the variability of the set of ranks. Thus, the correction for ties must be applied to the standard deviation of the sampling distribution of U. (page 124)

Since in much of the data of social science we must deal with large numbers of responses which are placed into a small number of ordinally scaled categories, ties are the rule rather than the exception, and we must make use of the Siegel correction. In such a case, it is appropriate to program a computer for the modified form of z_U which is given in the following equation:

$$(4.3)\quad z_U' = \frac{2U - \frac{nm}{3}}{\sqrt{\frac{nm}{3}\left[N + 1 - \frac{\Sigma(t^3 - t)}{N(N-1)}\right]}}$$

Where $N = n + m$

t = The number of tied items at any given rank (adding together ties from both groups)

Two biases result from this modification. First of all, it should be noted that neither the Auble tables nor the Mann-Whitney tables present critical values for U when tied ranks are present. As Siegel points out, the effect of ties is to slightly reduce variability, hence published tables are slightly <u>conservative</u> when used to judge a computed U which has <u>not</u> been adjusted for ties. On the other hand, to judge the significance of z_U' against a table of critical values for z_U is to <u>liberally</u> estimate the level of significance. Ideally, a set of tables of critical values for z_U' (and for U') should be derived for all possible combinations of ties, but such a set would be very bulky indeed. In practice it may be noted that the biasing errors are opposite in sign and of the same order of magnitude (although not exactly the same value, since one correction would apply to the relationship between a false and true critical tabular values,

while the other would apply to the relationship between a false tabular value and the true obtained one) - hence tend to cancel each other out. At any rate, it is difficult to obtain an error of greater absolute magnitude than 0.1 with n and m both less than 20 for either bias taken alone.

Tabular Use

The use of the following tables with machine calculated z_U's is simple. If either m or n is greater than 20, then z_U is assumed to be a normal deviate, and critical values given at the bottom of Table 4.20 (or obtainable from any table of areas and ordinates of the normal curve) are used. If both n and m $\leq$ 20, then the smaller is used to indicate which table to enter, the larger specifies the line of the table appropriate, and the obtained value for z_U must be larger than a listed critical value in order to be significant at the indicated level of probability. Probabilities listed are for a one-tailed test. If it is desired to test z_U against a two-tailed hypothesis, merely double the indicated values for level of significance.

Table 4.1

Tables of Critical Values For z_U For Small N's

Levels of Confidence

m	n	.001	.005	.01	.02	.025	.04	.05	.10
1	1	-	-	-	-	-	-	-	-
1	2	-	-	-	-	-	-	-	-
1	3	-	-	-	-	-	-	-	-
1	4	-	-	-	-	-	-	-	-
1	5	-	-	-	-	-	-	-	-
1	6	-	-	-	-	-	-	-	-
1	7	-	-	-	-	-	-	-	-
1	8	-	-	-	-	-	-	-	-
1	9	-	-	-	-	-	-	-	1.567
1	10	-	-	-	-	-	-	-	1.581
1	11	-	-	-	-	-	-	-	1.593
1	12	-	-	-	-	-	-	-	1.604
1	13	-	-	-	-	-	-	-	1.612
1	14	-	-	-	-	-	-	-	1.620
1	15	-	-	-	-	-	-	-	1.627
1	16	-	-	-	-	-	-	-	1.633
1	17	-	-	-	-	-	-	-	1.638
1	18	-	-	-	-	-	-	-	1.644
1	19	-	-	-	-	-	-	1.648	1.474
1	20	-	-	-	-	-	-	1.652	1.486
2	2	-	-	-	-	-	-	-	-
2	3	-	-	-	-	-	-	-	1.732
2	4	-	-	-	-	-	-	-	1.852
2	5	-	-	-	-	-	-	1.936	1.549
2	6	-	-	-	-	-	2.000	2.000	1.667

m	n	.001	.005	.01	.02	.025	.04	.05	.10
2	7	-	-	-	-	-	2.049	2.049	1.757
2	8	-	-	-	-	2.089	2.089	1.828	1.567
2	9	-	-	-	2.121	2.121	1.886	1.887	1.650
2	10	-	-	-	2.148	2.148	1.934	1.934	1.504
2	11	-	-	-	2.172	2.172	1.974	1.974	1.579
2	12	-	-	-	2.192	2.009	2.009	1.826	1.461
2	13	-	-	2.207	2.037	2.037	1.868	1.868	1.528
2	14	-	-	2.222	2.063	2.063	1.905	1.905	1.587
2	15	-	-	2.235	2.086	2.086	1.937	1.788	1.490
2	16	-	-	2.247	2.107	2.107	1.826	1.826	1.545
2	17	-	-	2.258	2.125	1.992	1.859	1.859	1.461
2	18	-	-	2.268	2.142	2.016	1.890	1.764	1.512
2	19	-	2.277	2.157	2.037	2.037	1.917	1.797	1.438
2	20	-	2.284	2.170	2.056	2.056	1.828	1.828	1.485
3	3	-	-	-	-	-	-	1.964	1.527
3	4	-	-	-	-	-	2.121	2.121	1.768
3	5	-	-	-	2.236	2.236	1.938	1.938	1.640
3	6	-	-	-	2.324	2.066	2.066	1.807	1.549
3	7	-	-	2.393	2.165	2.165	1.937	1.937	1.481
3	8	-	-	2.449	2.245	2.041	2.041	1.837	1.429
3	9	-	2.495	2.311	2.126	2.126	1.941	1.941	1.571
3	10	-	2.536	2.367	2.198	2.029	1.860	1.860	1.522
3	11	-	2.568	2.412	2.101	2.101	1.946	1.790	1.479
3	12	-	2.453	2.309	2.164	2.020	1.876	1.876	1.443
3	13	-	2.488	2.354	2.085	2.085	1.950	1.816	1.412
3	14	-	2.520	2.394	2.142	2.016	1.890	1.764	1.386
3	15	-	2.429	2.310	2.073	2.073	1.836	1.836	1.481

m	n	.001	.005	.01	.02	.025	.04	.05	.10
3	16	-	2.459	2.348	2.124	2.012	1.900	1.789	1.453
3	17	2.700	2.488	2.276	2.170	2.065	1.853	1.747	1.376
3	18	2.714	2.513	2.312	2.111	2.010	1.809	1.809	1.407
3	19	2.727	2.440	2.344	2.153	2.057	1.866	1.770	1.388
3	20	2.738	2.465	2.282	2.099	2.008	1.826	1.734	1.369
4	4	-	-	-	2.309	2.309	2.021	2.021	1.443
4	5	-	-	2.449	2.205	2.205	1.960	1.960	1.470
4	6	-	2.558	2.345	2.132	2.132	1.919	1.919	1.492
4	7	-	2.646	2.457	2.268	2.079	1.890	1.890	1.512
4	8	-	2.547	2.377	2.207	2.037	1.868	1.868	1.528
4	9	-	2.623	2.315	2.160	2.160	1.852	1.852	1.389
4	10	2.829	2.546	2.405	2.122	2.122	1.839	1.839	1.414
4	11	2.872	2.611	2.350	2.089	2.089	1.828	1.828	1.436
4	12	2.911	2.547	2.304	2.183	2.062	1.819	1.819	1.455
4	13	2.831	2.605	2.378	2.152	2.038	1.812	1.812	1.472
4	14	2.868	2.549	2.337	2.124	2.018	1.806	1.806	1.381
4	15	2.900	2.500	2.300	2.100	2.000	1.800	1.800	1.400
4	16	2.834	2.551	2.362	2.078	1.984	1.889	1.701	1.417
4	17	2.866	2.508	2.329	2.150	2.060	1.881	1.702	1.433
4	18	2.810	2.554	2.299	2.129	2.043	1.873	1.703	1.362
4	19	2.839	2.514	2.352	2.109	2.028	1.865	1.703	1.379
4	20	2.866	2.479	2.324	2.091	2.091	1.859	1.704	1.394
5	5	-	2.611	2.402	2.402	2.193	1.985	1.776	1.567
5	6	-	2.557	2.374	2.192	2.192	2.009	1.826	1.461
5	7	-	2.679	2.354	2.192	2.029	1.867	1.867	1.542
5	8	2.928	2.635	2.343	2.196	2.050	1.903	1.757	1.464

m	n	.001	.005	.01	.02	.025	.04	.05	.10
5	9	2.867	2.600	2.333	2.200	2.067	1.933	1.800	1.400
5	10	2.939	2.572	2.327	2.082	2.082	1.837	1.715	1.470
5	11	2.890	2.550	2.323	2.096	2.096	1.870	1.756	1.416
5	12	2.952	2.530	2.319	2.109	2.003	1.898	1.792	1.371
5	13	2.908	2.514	2.316	2.119	2.021	1.824	1.725	1.429
5	14	2.963	2.593	2.315	2.130	2.037	1.852	1.759	1.389
5	15	2.924	2.575	2.313	2.139	2.052	1.877	1.702	1.353
5	16	2.890	2.560	2.312	2.147	2.064	1.817	1.734	1.404
5	17	2.938	2.546	2.311	2.076	1.998	1.841	1.763	1.371
5	18	2.907	2.534	2.311	2.087	2.013	1.789	1.714	1.342
5	19	2.878	2.523	2.310	2.097	2.026	1.812	1.741	1.386
5	20	2.921	2.514	2.310	2.106	2.038	1,834	1.698	1.359
6	6	-	2.562	2.402	2.242	2.082	1.922	1.761	1.441
6	7	3.000	2.571	2.429	2.143	2.143	1.857	1.857	1.429
6	8	2.970	2.582	2.324	2.195	2.066	1.937	1.808	1.420
6	9	2.946	2.593	2.357	2.121	2.004	1.886	1.768	1.414
6	10	2.928	2.603	2.386	2.169	2.061	1.844	1.735	1.410
6	11	2.915	2.613	2.412	2.111	2.010	1.809	1.709	1.407
6	12	2.998	2.529	2.342	2.155	2.061	1.874	1.780	1.405
6	13	2.982	2.544	2.368	2.105	2.018	1.842	1.754	1.404
6	14	2.969	2.557	2.392	2.144	2.062	1.814	1.732	1.402
6	15	2.958	2.569	2.336	2.102	2.024	1.791	1.713	1.401
6	16	2.949	2.580	2.359	2.138	1.990	1.843	1.696	1.401
6	17	2.940	2.520	2.310	2.100	2.030	1.820	1.750	1.400
6	18	2.933	2.533	2.333	2.067	2.000	1.800	1.733	1.333
6	19	2.927	2.545	2.354	2.100	2.036	1.782	1.718	1.336
6	20	2.921	2.556	2.313	2.069	2.009	1.826	1.704	1.339

m	n	.001	.005	.01	.02	.025	.04	.05	.10
7	7	3.003	2.620	2.364	2.109	2.109	1.853	1.725	1.470
7	8	3.009	2.546	2.431	2.199	2.083	1.852	1.736	1.389
7	9	3.017	2.594	2.382	2.170	2.065	1.853	1.747	1.429
7	10	2.928	2.538	2.343	2.147	2.050	1.855	1.757	1.367
7	11	2.944	2.582	2.400	2.129	2.038	1.857	1.766	1.404
7	12	2.959	2.536	2.367	2.113	2.029	1.860	1.775	1.352
7	13	2.971	2.575	2.338	2.100	2.021	1.862	1.704	1.387
7	14	2.984	2.536	2.387	2.089	2.014	1.790	1.716	1.343
7	15	2.996	2.573	2.362	2.080	2.009	1.798	1.727	1.375
7	16	3.007	2.539	2.339	2.072	2.005	1.804	1.737	1.336
7	17	2.953	2.572	2.318	2.064	2.001	1.810	1.683	1.366
7	18	2.965	2.542	2.360	2.118	1.997	1.815	1.694	1.331
7	19	2.977	2.572	2.341	2.110	1.994	1.821	1.705	1.358
7	20	2.988	2.545	2.324	2.102	1.992	1.826	1.715	1.328
8	8	2.941	2.626	2.416	2.101	1.996	1.891	1.787	1.366
8	9	2.984	2.599	2.406	2.117	2.021	1.829	1.732	1.347
8	10	3.021	2.577	2.399	2.132	2.044	1.866	1.777	1.422
8	11	2.973	2.560	2.395	2.147	2.064	1.817	1.734	1.404
8	12	3.009	2.546	2.392	2.083	2.006	1.852	1.698	1.389
8	13	2.969	2.534	2.317	2.100	2.028	1.810	1.665	1.376
8	14	3.003	2.594	2.321	2.116	2.048	1.843	1.706	1.365
8	15	2.970	2.582	2.324	2.130	2.001	1.808	1.743	1.356
8	16	3.001	2.572	2.327	2.082	2.021	1.837	1.715	1.347
8	17	2.971	2.563	2.330	2.097	1.981	1.806	1.689	1.340
8	18	3.000	2.556	2.333	2.111	2.000	1.778	1.722	1.333
8	19	2.973	2.548	2.336	2.071	2.018	1.805	1.699	1.327
8	20	3.900	2.543	2.339	2.085	1.983	1.780	1.678	1.322

m	n	.001	.005	.01	.02	.025	.04	.05	.10
9	9	2.958	2.605	2.340	2.075	2.075	1.810	1.722	1.369
9	10	3.022	2.613	2.368	2.123	2.042	1.797	1.715	1.388
9	11	3.002	2.546	2.394	2.090	2.014	1.862	1.710	1.406
9	12	2.985	2.559	2.345	2.132	1.990	1.848	1.706	1.350
9	13	2.972	2.571	2.371	2.104	2.037	1.836	1.703	1.369
9	14	3.024	2.583	2.331	2.079	2.016	1.827	1.701	1.386
9	15	3.011	2.594	2.355	2.117	1.998	1.819	1.699	1.342
9	16	3.000	2.547	2.321	2.095	1.981	1.811	1.698	1.359
9	17	2.991	2.560	2.344	2.075	2.021	1.805	1.698	1.320
9	18	2.984	2.572	2.315	2.109	2.006	1.800	1.698	1.337
9	19	2.976	2.582	2.336	2.091	1.992	1.795	1.697	1.353
9	20	3.017	2.545	2.357	2.074	1.980	1.791	1.697	1.320
10	10	3.023	2.570	2.343	2.116	2.041	1.738	1.738	1.361
10	11	3.028	2.606	2.324	2.113	2.042	1.831	1.690	1.338
10	12	3.033	2.572	2.374	2.110	2.044	1.846	1.714	1.385
10	13	2.977	2.543	2.357	2.109	1.984	1.798	1.736	1.364
10	14	2.986	2.576	2.342	2.108	1.991	1.815	1.698	1.347
10	15	2.995	2.551	2.329	2.108	1.997	1.830	1.719	1.331
10	16	3.004	2.582	2.319	2.108	2.003	1.792	1.686	1.370
10	17	3.013	2.561	2.360	2.109	2.009	1.808	1.707	1.356
10	18	3.021	2.541	2.350	2.110	2.014	1.774	1.678	1.343
10	19	3.028	2.569	2.340	2.065	1.973	1.789	1.698	1.331
10	20	2.992	2.552	2.332	2.068	1.980	1.804	1.672	1.320
11	11	2.988	2.594	2.331	2.068	2.003	1.806	1.740	1.346
11	12	3.015	2.585	2.338	2.092	2.031	1.785	1.723	1.354
11	13	2.984	2.578	2.346	2.115	1.999	1.825	1.709	1.362
11	14	3.011	2.573	2.354	2.080	2.026	1.807	1.697	1.369

m	n	.001	.005	.01	.02	.025	.04	.05	.10
11	15	3.036	2.569	2.361	2.102	1.998	1.790	1.687	1.323
11	16	3.010	2.566	2.319	2.073	2.023	1.776	1.678	1.332
11	17	3.034	2.563	2.328	2.093	1.999	1.811	1.717	1.341
11	18	3.011	2.562	2.337	2.067	2.978	1.798	1.708	1.348
11	19	3.034	2.561	2.346	2.087	2.001	1.786	1.700	1.356
11	20	3.014	2.560	2.353	2.064	1.982	1.775	1.693	1.321
12	12	3.002	2.598	2.367	2.079	2.021	1.790	1.732	1.328
12	13	2.992	2.556	2.339	2.067	2.013	1.795	1.686	1.360
12	14	3.035	2.572	2.366	2.109	2.006	1.800	1.698	1.337
12	15	3.025	2.586	2.342	2.098	2.000	1.805	1.708	1.317
12	16	3.018	2.553	2.321	2.089	1.996	1.811	1.671	1.346
12	17	3.011	2.568	2.347	2.081	1.992	1.815	1.683	1.328
12	18	3.006	2.583	2.329	2.075	1.990	1.778	1.693	1.312
12	19	3.001	2.555	2.352	2.068	1.987	1.784	1.703	1.338
12	20	3.036	2.569	2.336	2.063	1.985	1.791	1.674	1.323
13	13	3.000	2.590	2.333	2.077	2.026	1.821	1.718	1.359
13	14	3.009	2.572	2.330	2.087	1.990	1.796	1.699	1.359
13	15	3.017	2.556	2.326	2.096	2.004	1.773	1.681	1.359
13	16	3.026	2.587	2.324	2.105	1.973	1.798	1.710	1.316
13	17	3.034	2.574	2.323	2.072	1.988	1.779	1.695	1.318
13	18	3.002	2.562	2.322	2.082	2.002	1.801	1.681	1.321
13	19	3.012	2.590	2.321	2.091	1.976	1.784	1.669	1.324
13	20	3.021	2.579	2.321	2.063	1.990	1.805	1.695	1.326
14	14	3.032	2.573	2.343	2.068	1.976	1.792	1.700	1.332
14	15	3.011	2.575	2.357	2.095	2.007	1.789	1.702	1.353
14	16	3.035	2.577	2.328	2.079	1.995	1.788	1.704	1.330

m	n	.001	.005	.01	.02	.025	.04	.05	.10
14	17	3.016	2.580	2.342	2.064	2.064	1.786	1.667	1.349
14	18	3.039	2.583	2.317	2.089	1.975	1.785	1.671	1.330
14	19	3.023	2.550	2.331	2.076	2.003	1.785	1.675	1.311
14	20	3.010	2.730	2.345	2.065	1.995	1.785	1.680	1.330
15	15	3.007	2.551	2.343	2.095	2.012	1.804	1.680	1.348
15	16	3.043	2.569	2.332	2.095	1.976	1.779	1.700	1.344
15	17	3.040	2.549	2.322	2.096	1.983	1.794	1.681	1.341
15	18	3.037	2.567	2.350	2.061	1.988	1.772	1.699	1.338
15	19	3.035	2.549	2.341	2.064	1.994	1.786	1.682	1.335
15	20	3.033	2.567	2.333	2.067	2.000	1.800	1.667	1.333
16	16	3.015	2.563	2.337	2.073	1.997	1.771	1.696	1.319
16	17	3.026	2.558	2.341	2.089	1.981	1.801	1.693	1.333
16	18	3.036	2.553	2.346	2.070	2.001	1.794	1.691	1.311
16	19	3.046	2.583	2.318	2.086	1.987	1.788	1.689	1.325
16	20	3.025	2.579	2.324	2.069	1.974	1.783	1.687	1.305
17	17	3.186	2.566	2.325	2.084	1.980	1.774	1.670	1.326
17	18	3.036	2.574	2.343	2.079	1.980	1.782	1.683	1.320
17	19	3.025	2.549	2.328	2.074	1.979	1.789	1.663	1.314
17	20	3.047	2.560	2.346	2.072	1.981	1.767	1.676	1.310
18	18	3.037	2.562	2.341	2.088	1.993	1.772	1.677	1.329
18	19	3.039	2.552	2.340	2.066	1.975	1.793	1.671	1.307
18	20	3.040	2.573	2.339	2.076	1.988	1.783	1.666	1.316
19	19	3.021	2.554	2.321	2.058	1.971	1.766	1.679	1.328
19	20	3.035	2.557	2.332	2.079	1.995	1.770	1.686	1.321
20	20	3.029	2.570	2.326	2.083	1.975	1.785	1.677	1.325
Normal		3.090	2.576	2.326	2.054	1.960	1.751	1.645	1.282